COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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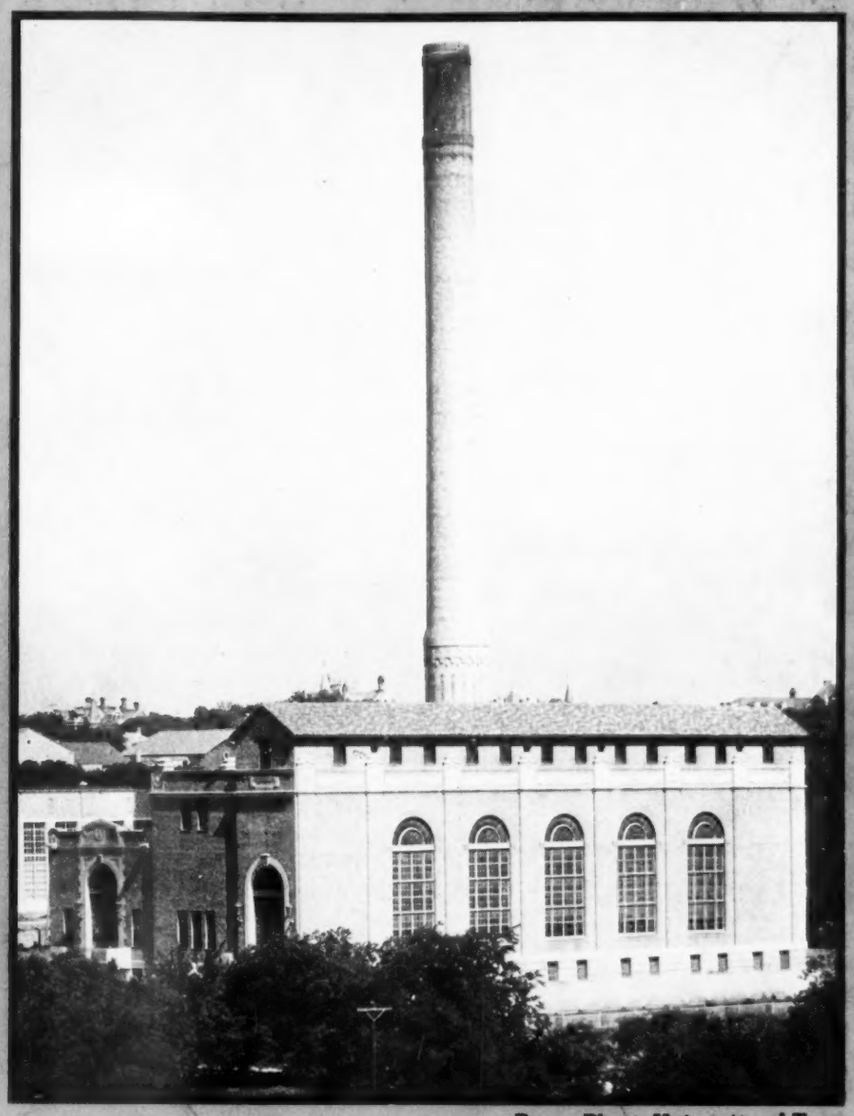


Power Plant, University of Texas

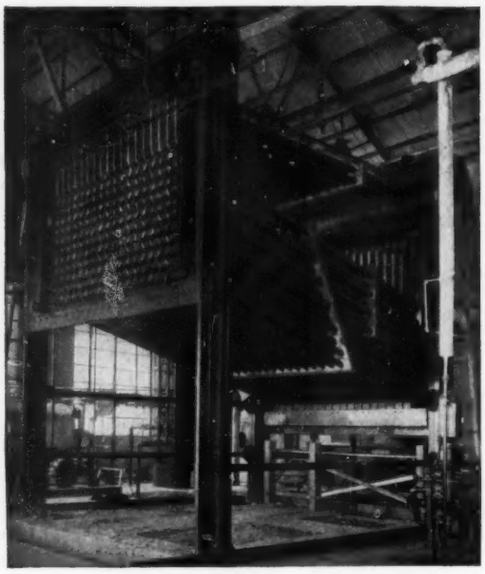
Lignite Burned on Traveling Grates at University of Texas

Chlorination of Condenser Water

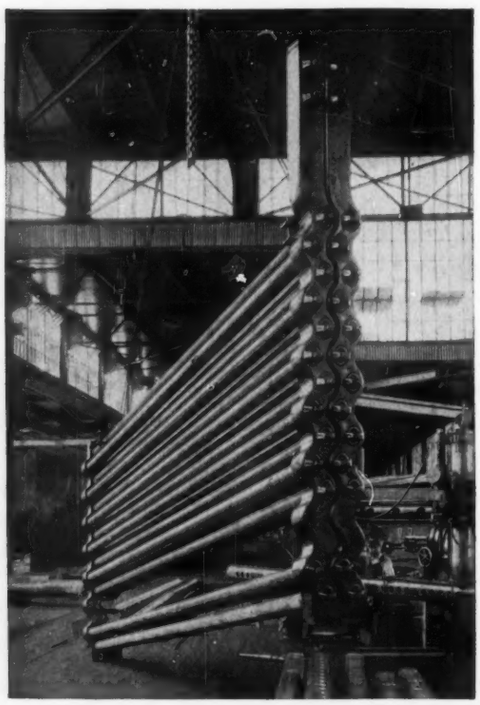
MODERN STEAM PLANT EQUIPMENT

No. 5 *of a series presenting design and operating features of C-E products*

C-E SECTIONAL HEADER BOILER



Installation view showing boiler and supporting steel



Two assembled sections composed of tubes, headers and handhole fittings

FEATURES

Drum . . . Fusion welded seams. Riveted construction optional.

Tubes . . . Made of seamless steel tubing. Any tube may be replaced without disturbing the refractory baffles or any part of the boiler.

Headers . . . Made of seamless steel tubing forged into a sinuous header. Open ends of headers are closed by a square block having a groove into which the ends of the header are crimped by hydraulic pressure. The remainder of the groove is then filled by electric welding to prevent corrosion. The weld is not depended on for tightness or strength. This arrangement is patented and permits the use of a thicker end block than is used with hand forged welds. The handholes have machined inside faces and the handhole plates are designed for easy adjustment of the gaskets.

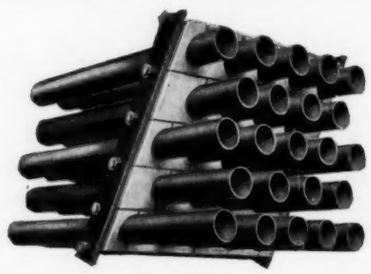
Circulators . . . Two rows of horizontal circulators connect the upper end of the uptake header and the drum, giving adequate outlet area for low steam velocities, thus assuring minimum moisture content in steam delivered to the drum.

Baffles . . . Heavy, specially designed, burned tile held together by rods extending through the boiler. Not affected by expansion or contraction of the boiler.

Superheater . . . Either interdeck or above-deck superheater may be installed.

Supporting Structure . . . Boiler is supported entirely by steelwork which is independent of the brickwork.

Steam Quality . . . With proper conditions of feedwater, moisture content of steam will not exceed a small fraction of 1 per cent.



Baffle construction

View showing patented method of closing end of header

Handhole fittings—plate, gasket, yoke, washer and nut

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX NUMBER ONE

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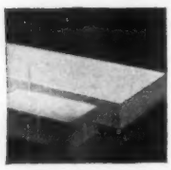

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EDITORIAL

A National Society for Professional Engineers

The interests of the engineer are two-fold—technical and professional. The former breaks down into the numerous branches of engineering whereas the latter is a common interest involving professional standing, through licensing, public recognition and advancement in economic status. The technical aspects are being adequately served by the various engineering societies which, also, through cooperative effort, have made a creditable start toward raising and unifying requirements for membership, and in presenting the engineering viewpoint concerning many national and local projects.

There are, however, certain limitations beyond which societies organized along technical lines cannot go, and there are many engineers who believe that experiences of the past three years have shown the need for a united effort to place the professional standing of the engineer on a par with the legal and the medical professions.

With this purpose in view the National Society of Professional Engineers was born on May 25 under the sponsorship of the New York State Society of Professional Engineers in conjunction with similar organizations from seven other states. The objectives are:

1. To advance and protect the interests of the engineer, individually and collectively, through united effort, legislation and public relations.
2. To promote the economic, legislative and social interests of the engineer.
3. To act whenever the interests of the profession can be promoted or are jeopardized.
4. To maintain and strengthen the solidarity of the engineering profession.
5. To strengthen, unify, extend and enforce registration laws and other legislation protecting the practice of engineering and the designation "engineer."
6. To strengthen, coordinate, unify and extend state societies of professional engineers and county chapters.
7. To protect the engineer against exploitation, unprofessional competition, unlawful encroachment and restriction of rights of practice.
8. To wage a militant campaign for more adequate compensation for engineering services.
9. To promote cooperative and fraternal relations.
10. To encourage and guide younger engineers.
11. To improve conditions of employment and methods of engaging engineering services.
12. To extend employment service, and build up a reserve fund for assisting engineers in distress.
13. To represent a united engineering profession in governmental councils.
14. To serve as the voice of the profession where the engineer is especially qualified to supply sound analysis and guide public policy on fundamental questions of national, economic, industrial and social import.
15. To conduct a planned campaign for public recognition of the engineering profession.

Full membership in the National Society will be restricted to professional engineers registered in any state or certified by the National Bureau of Engineering Registration. State and local chapters will not be deprived of their autonomy. It is anticipated that about sixteen hundred members of the American Association of Engineers, which at one time actively pursued some of these objectives but which has been less active in recent years, will qualify for membership in the new Society. It is expected that the organization will be completed and in full swing by the first of the year with headquarters in Washington, D. C.

While some of the proposed activities of the National Society of Professional Engineers will parallel existing activities of the Founder Engineering Societies it is believed that the efforts can be coordinated so as to avoid duplication.

Capital Goods and the Utilities

In his presidential address at the recent Annual Convention of the Edison Electric Institute, at Atlantic City, George B. Cortelyou cited figures to show that in normal times the electric light and power industry ranks first as purchasers of durable goods. From 1922 to 1932 it spent seven and a half billion dollars for new construction which was more than that spent for highways throughout the country or by the railroads. Even as late as 1930 it spent over nine hundred million which involved a monthly payment for wages over twice that expended by the Government on Federal projects financed by the PWA, as reported for March 1934.

However, during 1933 the expenditure for construction by the electric light and power industry was less than one-fifth the yearly average for the preceding ten years. With the sales of electricity now steadily coming back, under the stimulus of lower rates and increasing industrial activity, the time may not be far off when excess capacity will be absorbed and extensions or rehabilitation of existing facilities will again be necessary.

The extent to which this situation can be anticipated will depend largely upon three factors, namely, constructive administration of the Securities Act, a halt in the rush to burden utilities with additional taxes so that earnings may attract new capital, and a more intelligent consideration of municipal plant projects.

It is paradoxical that while the Government is striving to stimulate the movement of capital goods certain elements within the Government, together with much local political and public opinion, are apparently endeavoring to hamstring an industry that in the past has been the largest factor in capital goods buying.

As Mr. Cortelyou observed, "violations of the law should be punished, but resentment should not be vented upon an entire industry."

Lignite Burned on Traveling Grates at University of Texas

By CARL J. ECKHARDT, Jr.
Adjunct Professor of Mech. Eng.
University of Texas
and
WALTER H. WOOD
Combustion Engineering Company, Inc.

Although natural gas and fuel oil are the prevailing fuels in the State of Texas, large deposits of lignite abound therein, and the University of Texas, at Austin, has found it more economical to utilize lignite for its new steam generating unit which serves the full steam and power demands of the large group of university buildings. The lignite is burned on a traveling grate stoker. Successive steps in the burning of this fuel since the original installation of 1910 are reviewed and both test and performance data for the unit are included.

OF THE lignitic coals, which comprise approximately 27 per cent of the nation's reserve coal tonnage, 23,000,000,000 tons are deposited in the State of Texas. This vast fuel reserve remains to date practically untouched. As may be seen in Fig. 1, these lignite fields in Texas embrace an area of approximately 60,000 square miles. Despite the vast expanse of these lignite fields, most power, heating and industrial plants in this state burn natural gas and fuel oil. Texas ranks among the foremost producers of the last mentioned fuels. The comparatively small utilization of lignite must, in a large measure, be attributed to the prolific production of and the ease with which these two more admirable fuels may be transported and consumed.

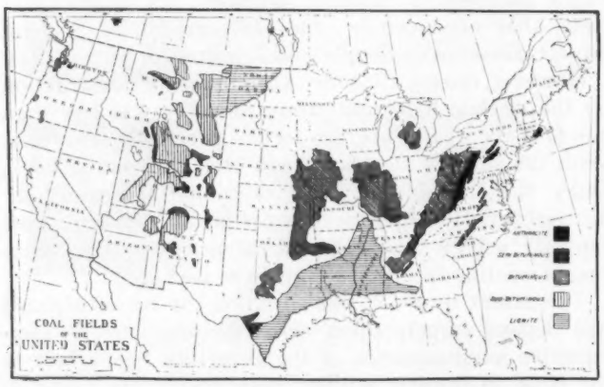

Fig. 1—Map showing coal fields of the United States

The irregular but persistent decline in fuel oil production and the distribution of enormous quantities of natural gas to distant points through vast distribution systems have caused engineers interested in the generation of steam to concern themselves with the combustion of the state's less admirable types of fuel. Both the rate at which natural gas and oil reserves within the state will be exploited and the rate of their future consumption are uncertain. The subsequent date at which oil and gas reserves will have been exhausted, insofar as their use for steam generating purposes are concerned, is a matter of conjecture. As their production continues their availability for steam generating purposes will ultimately decline. For this reason it seems safe to predict that this comparatively young and hitherto unused fuel, lignite, even though it contains by weight from 25 to 40 per cent moisture, will ultimately be very intimately connected with the industrial development of the State of Texas.

The engineers of the University of Texas early recognized and appreciated the importance which the use of lignite would ultimately assume. The development of lignite for firing in pulverized form had of necessity to be conducted by the larger public service utilities possessed of plants of a sufficient size and magnitude to justify the installation of equipment which pulverized fuel firing necessitated. For this reason efforts at the University of Texas, which were intended to encourage the use of lignite for steam generating purposes, by making available reliable information relative to its use, were confined to experimentation with lignite as a grate-fired fuel.

Texas lignite was originally used in the institution's heating plant where it was hand-fired on stationary grates. The nature of the arrangement employed in this installation of 1910 may be seen by reference to Fig. 3. The heat balance which is shown in Table I, is typical of the equipment shown.

With natural draft it was necessary to provide large air openings in the grate to secure sufficient air for com-

bustion. The lignite disintegrated as it burned so that sifting losses through the fuel bed were large. The cooling surfaces of the boiler tubes were located so close to the grate that the combustible gases arising from the fuel bed were chilled before combustion could be completed. Lignite could, however, be purchased at a very low cost. The economies effected justified the continued use of this fuel for steam generating purposes. The use of this simple equipment did provide a sufficient amount of basic information to permit the conception of means by which the original performance could be materially improved.

In 1927 the University constructed a new heating and power plant. In practically every detail this plant was designed to overcome difficulties which had been experienced in the operation of the original lignite burning equipment. The general arrangement of the steam generating system installed in 1927 is shown in Fig. 4.

Simple automatic coal-handling equipment was installed so that "run of mine" lignite could be reduced to a more uniform size. Each boiler was provided with a front overfeed type of stoker arranged with horizontal air openings to prevent sifting losses previously encountered. The stokers had overlapping male and female tops, a complete differential kicking movement for actuating the fuel from the front to the rear of the furnace and sectional top ash-cut-out bars by means of which the refuse could be discharged into the ash pit. This arrangement is shown in Fig. 5.

This equipment was placed in operation in 1928. Test and operating records revealed that Texas lignite could be burned in a satisfactory manner. The use of this equipment, furthermore, revealed that many of the disadvantages commonly associated with the combustion of lignite on a grate surface were grossly exaggerated due, no doubt, to the application of improper fuel burning equipment. A considerable improvement in the operating characteristics of this equipment may be observed when the results which follow are compared with those previously shown for the original equipment.

TABLE I—TYPICAL HEAT BALANCE OF 1910 INSTALLATION

	Btu per lb "as recd"	Per cent
Heating value of fuel	7066	100.0
Heat absorbed by water and steam	3715	52.6
Heat loss due to moisture in lignite	457	6.5
Heat loss due to water from hydrogen in lignite	301	4.2
Heat loss due to moisture in air	36	0.5
Heat loss due to dry chimney gases	1109	15.7
Heat loss due to incomplete combustion	715	10.1
Heat loss due to unconsumed carbon	422	6.0
Radiation and unaccounted for losses	311	4.4
	7066	100.0

TABLE II—TYPICAL HEAT BALANCE OF 1927 INSTALLATION

	Btu per lb "as recd"	Per cent
Heating value of fuel	7205	100.0
Heat absorbed by water and steam	4683	65.0
Heat loss due to moisture in lignite	433	6.0
Heat loss due to water from hydrogen in lignite	298	4.1
Heat loss due to moisture in air	29	0.4
Heat loss due to dry chimney gases	1117	15.5
Heat loss due to incomplete combustion	0	0.0
Heat loss due to unconsumed carbon	158	2.2
Radiation and unaccounted for losses	487	6.8

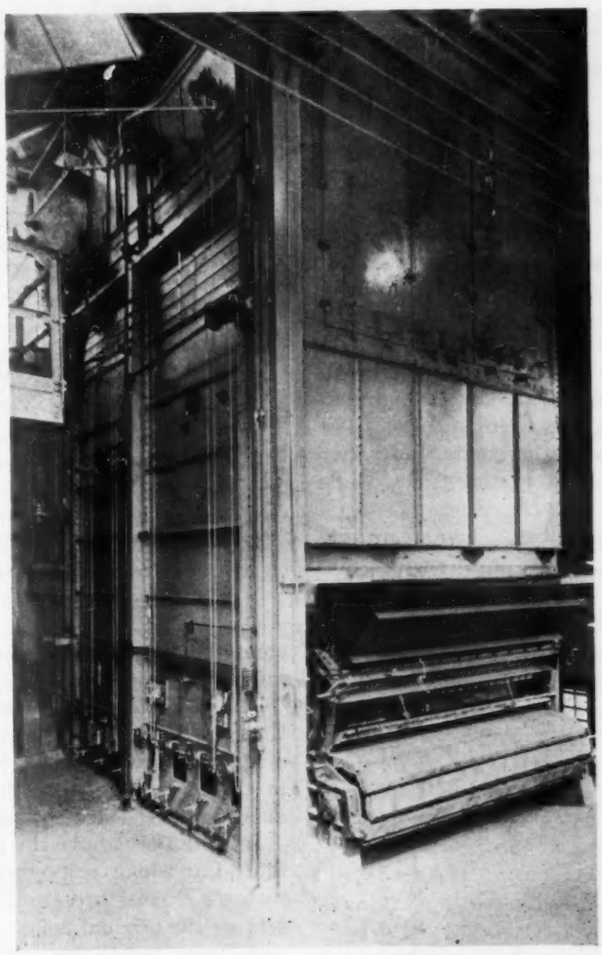

Fig. 2—New steam generating unit complete

In 1931 the University of Texas found itself in a position to finance a $5,000,000 building program. The demand for steam to be used for power generation and heating purposes was practically doubled by the simultaneous construction of nine large buildings. Specifications were for that reason prepared for additional steam generating equipment. A very careful analysis was made to determine the institution's policy with regard to the fuel which it would consume. After carefully considering proposals on lignite, fuel oil and natural gas, a conclusion to continue the use of lignite as a fuel was reached. This material is shaft mined by Mexican labor within thirty-five miles of the plant.

The specifications called for the installation of an entire steam generating system by one company in order that all divisions of responsibility could be eliminated. A paucity of floor space made necessary the concentration of four times as much capacity per unit of floor space as had previously been designed. In order that "clinkering" and "avalanching" tendencies which had been experienced with the installation of 1927 might be eliminated, stoker equipment capable of burning Texas lignite without any agitation whatever was called for. It was hoped that by this means the loss due to unconsumed carbon in the refuse could be further reduced. A superheater and air preheater were called for in order that the exit gas temperatures might be lowered so that heat losses due to dry chimney gases, to moisture in the fuel, and to the evaporation of the water formed by burning the hydrogen in the fuel could be materially reduced. In order that a proper air supply for all loads

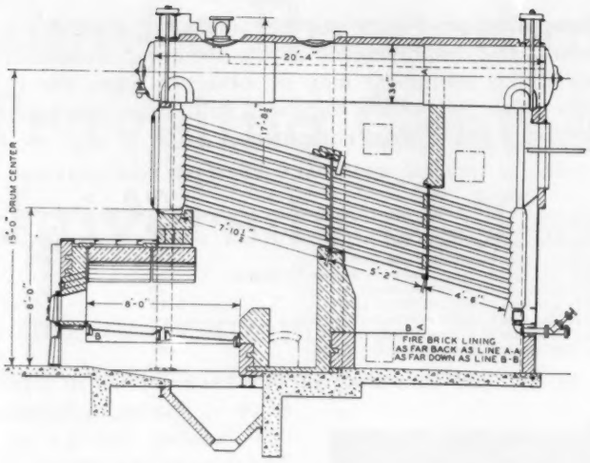

Fig. 3—Cross-section of 1910 boiler unit

could be provided, a stoker having a zoned air supply system was favored. A combustion control system was required in order that both fuel feed and air supply could be properly regulated.

A side elevation showing the general arrangement of the steam generating system as installed, together with the overhead fuel bunker, weigh larry, control cubicle and instrument panel are shown in Fig. 6.

The boiler is of the Hedges-Walsh-Weidner sectional-header, cross-drum type 20 tubes wide and 15 high and contains 7250 sq ft of water and gas swept surface. The front headers are connected with the steam and water drum by two horizontal rows of circulating tubes, while the rear headers are connected with the drum by a single row of 4 in. vertical circulating tubes. The steam and water drum is fusion welded, 54 in. in diameter and 18 ft long.

The boiler is set 18 ft 6 in. high from the floor to the bottom of the front headers, and is enclosed in a brick setting 22½ in. thick, backed up by 2½ in. of insulating material, on the outside of which is a panelled steel casing. The roof consists of 3 in. T-tile over the circulating tubes covered by 2½ in. of firebrick and a ½ in. thick hard cement finish. A soot hopper is provided underneath the second and third passes and arranged with suitable gates and chutes for returning any ash and cinders which accumulate in the hopper, into the rear of the furnace. Internal surfaces of all pressure parts were given two coats of No. 1 Apexior before the unit was put into service.

The boiler is equipped with Diamond soot blowers having six 1½ in. diameter revolving elements of the valve-in-head type.

An SC feedwater regulator is installed for controlling the rate of feeding of water to the boiler. Consolidated Ashcroft safety valve, feed valves and steam pressure gages, and Yarway water column and blow-off valves comprise the boiler appurtenances furnished with the unit.

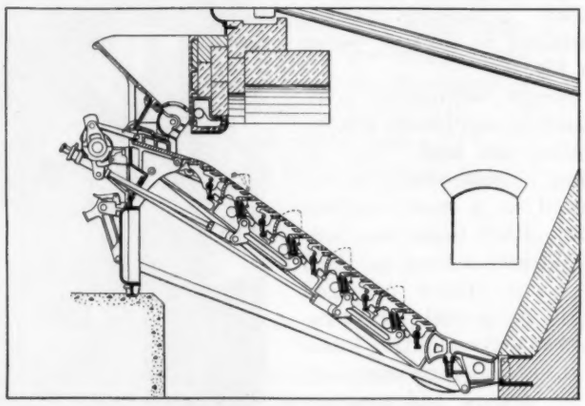

Fig. 5—Stoker of 1927 installation

A C-E plate-type air preheater is installed, having a total plate area of 3240 sq ft and designed to withstand a gas temperature of 800 F. Cinders which accumulate in the hopper underneath the preheater are blown by air into the furnace through the rear wall.

Immediately above the preheater is a Sirocco induced-draft fan which delivers the gases from the preheater through a steel breeching into a radial brick chimney, serving the original boilers in the plant in addition to the new steam generating unit. The fan, which is capable of handling 60,250 cu ft of gas per min is driven by a 100-hp G. E. motor having a speed range from 340 to 720 rpm. Air for combustion is delivered through the preheater by an American Blower fan, capable of handling 28,000 cu ft of 100 F air at 7 in. water pressure. This fan is driven by a 400 hp G. E. motor having a speed range varying from 600 to 1800 rpm. The hot air ducts are located underneath the boiler room floor, one on each side of the stoker with an equalizing duct between the two branch ducts which serve the stoker.

The unit is fired by a Coxe traveling grate stoker 12 ft wide and 21 ft long, having an effective fuel burning area of 242 sq ft. There are eight compartments in the stoker for controlling the rate and distribution of burning of the fuel. Air for combustion is introduced into

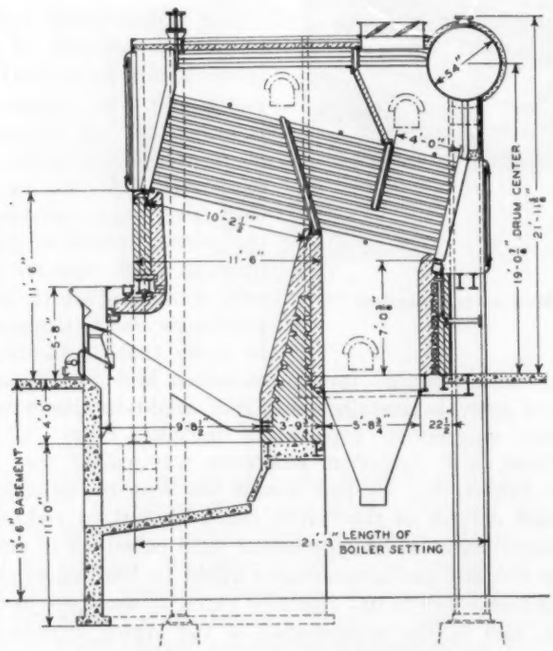

Fig. 4—Cross-section of 1927 installation

the several compartments from both sides of the stoker through dampers with handwheel control which permit of close adjustment of air supply to any portion of the fuel bed. The grate surface is composed of flat top "piano keys" carried on maleable iron dovetail strips bolted to cast-iron carrier bars. These bars are in two sections lengthwise and are attached to four forged-steel drive chains. The stoker is driven by a 5-hp constant-speed motor through a suitable worm and gear reduction and a Reeves variable-speed drive. This drive affords a range in speed of the grate from a minimum of 10 ft per hr to a maximum of 50 ft per hr. A fuel regulating gate controls the thickness of the fuel as it is fed onto the grate from the stoker hopper.

Special Furnace Design

The design of the furnace deserves special mention. Furnaces formerly designed for burning lignite on traveling grate stokers were usually of the front arch type such as are used in burning mid-west bituminous coals. A short stub arch over the rear of the stoker was sometimes installed, in addition to the main front arch. Owing to the high moisture content of lignite, such furnaces were not as satisfactory as could be desired, especially where combustion rates and maximum efficiencies were factors. Stratification of gases occurs in front arch furnaces, and in addition, most of the solid fuel which is lifted from the fuel bed, is carried with the gas stream into the boiler passes, or blown to the rear of the furnace and is lost in the ashpit.

The furnace employed in connection with the new steam generating unit and illustrated in Fig. 6 is of the rear arch type which is quite generally used for burning coke breeze and the smaller sizes of anthracite. The Detrick arch in this particular installation extends forward a distance of about 16 ft from the rear wall of the boiler and covers the rear five compartments of the stoker. It is located horizontally and at such a distance above the grate that flame and gases from the rear portion of the stoker sweep forward over the entire length of the fuel bed, removing moisture from the fuel as it enters the furnace and insuring prompt and stable ignition even at low rates of burning. As the combustion rate is increased and a greater amount of fuel is burned under the arch, a larger volume of gases is swept over the fuel bed and the speed of ignition is increased. The rear arch acts as a baffle for directing the rather lean gases from the rear of the furnace into intimate contact with the combustible gases from the forward part of the fuel bed. A thorough mixing of gases occurs in the lower part of the furnace and stratification is almost entirely prevented. Any solid fuel which is lifted from the grate is carried forward and dropped out of the gas stream onto the fuel bed. Solid carbon losses both in the ashpit and in the boiler setting are small with this rear arch type of furnace.

There is a rectangular steel water box installed along each side wall above the stoker for preventing the disturbance of the fuel bed by an accumulation of clinkers on the walls. These side wall boxes are connected in the boiler circulation, and extend the entire length of the furnace.

The burning of the fuel on the stoker is regulated by the Hagan system of combustion control. This system

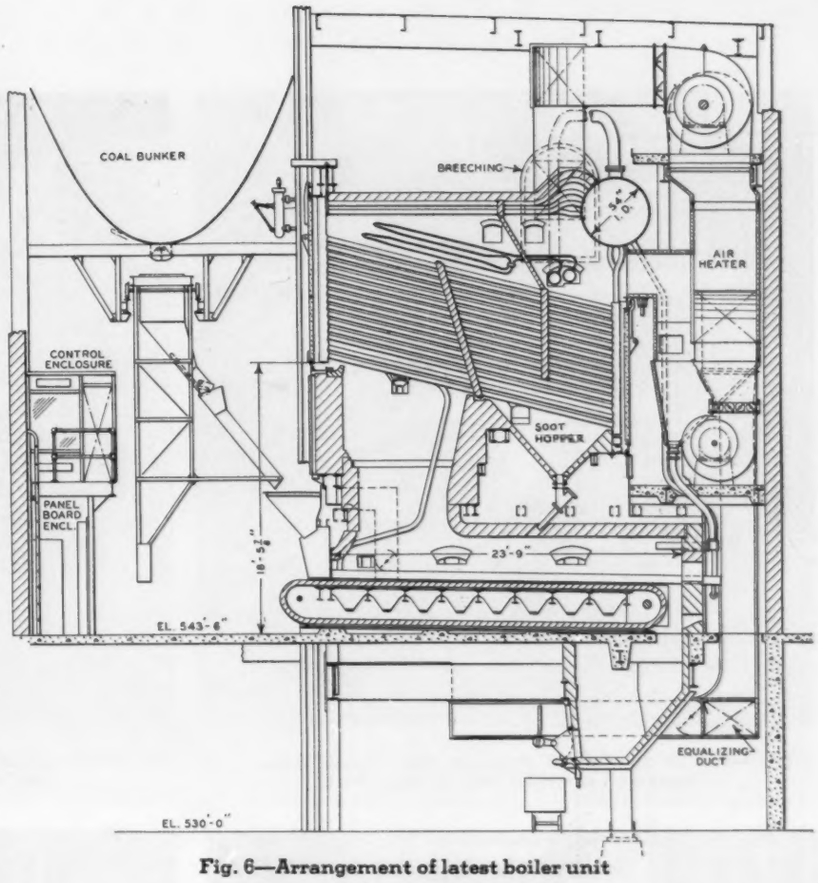

Fig. 6—Arrangement of latest boiler unit

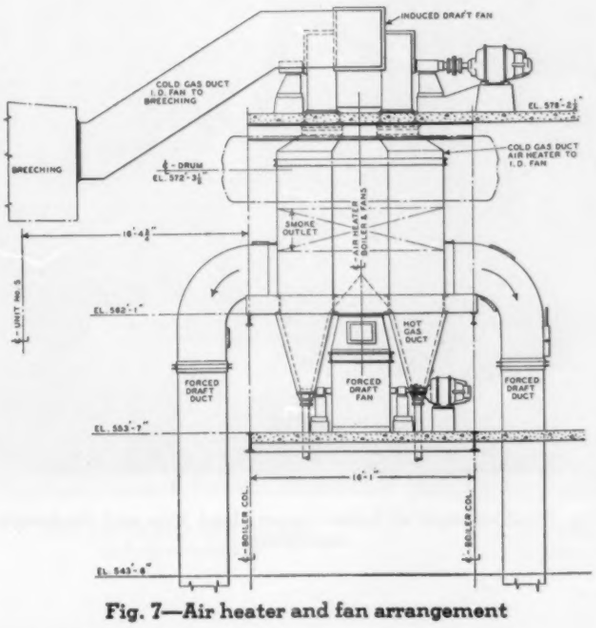

Fig. 7—Air heater and fan arrangement

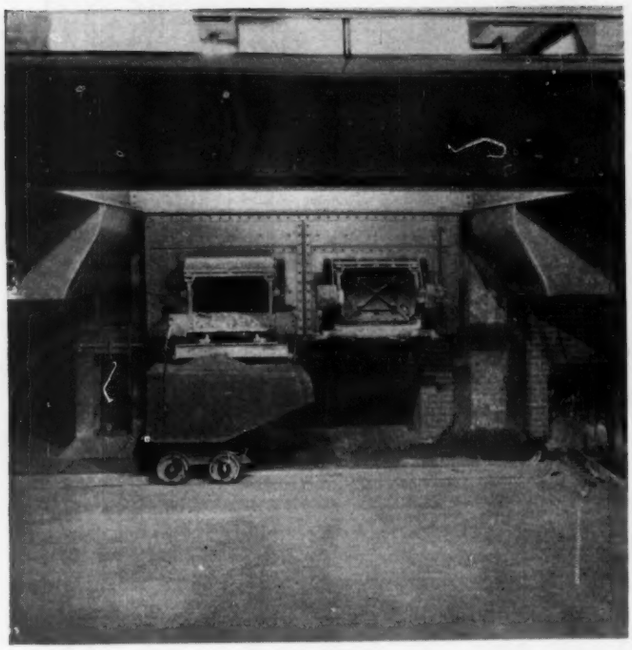

Fig. 8—Ash is discharged through two hopper gates into cars and emptied into a skip hoist

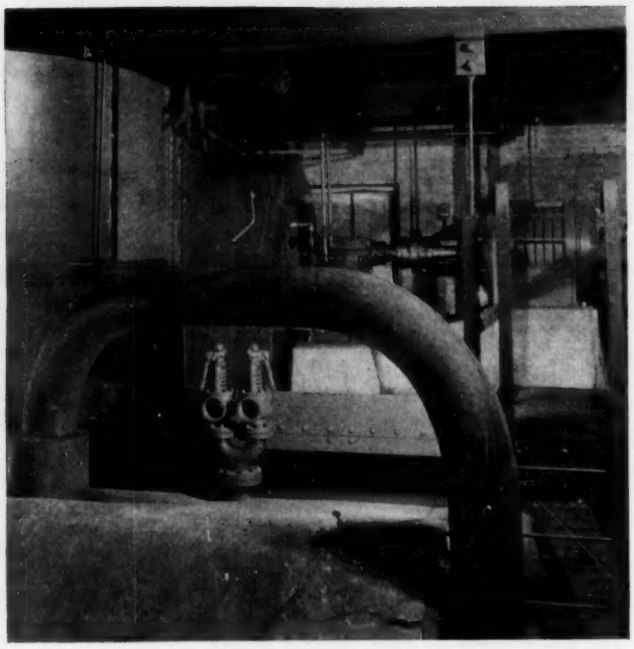

Fig. 9—Above the air heater is located the induced-draft fan which discharges to the stack

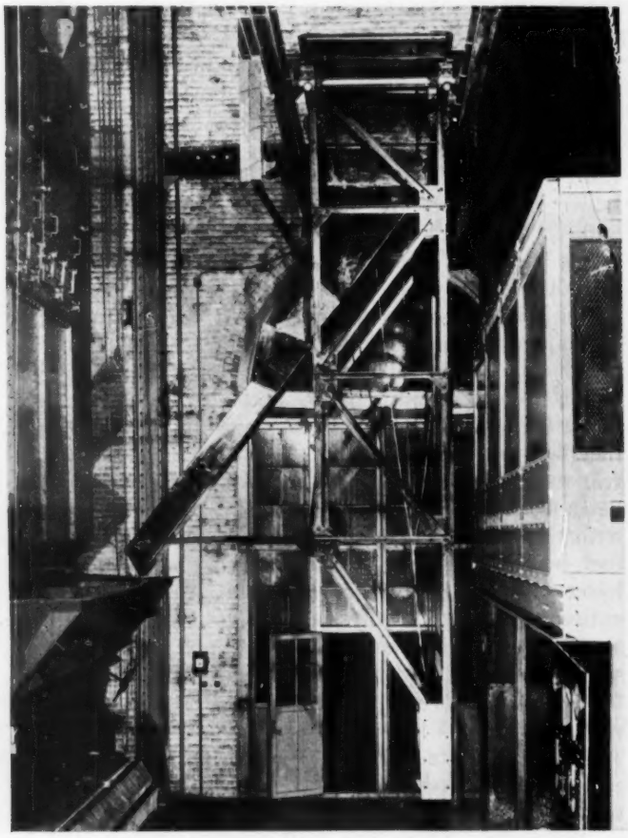

Fig. 10—The lignite is discharged from an overhead bunker to a traveling weigh larry, thence to the stoker hopper

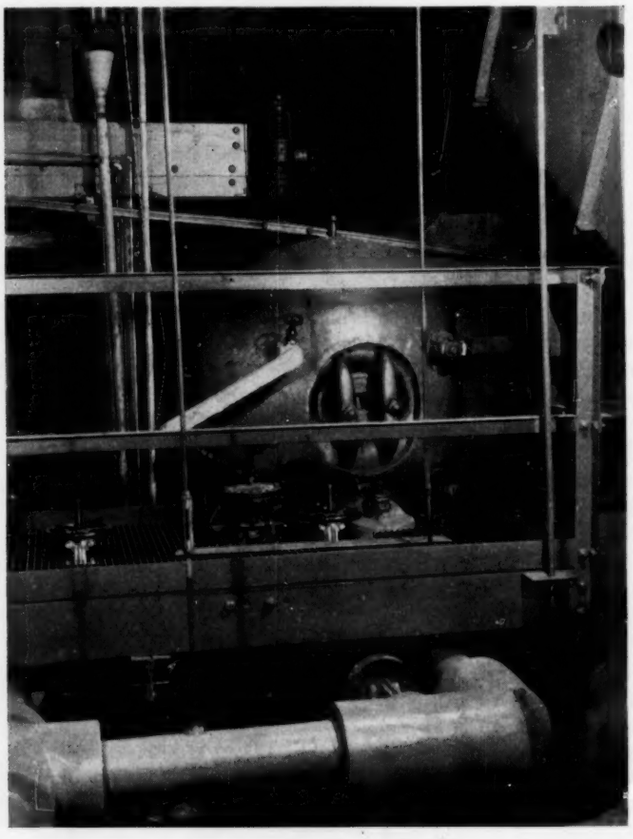

Fig. 11—End view of boiler drum, feed line and feedwater regulator

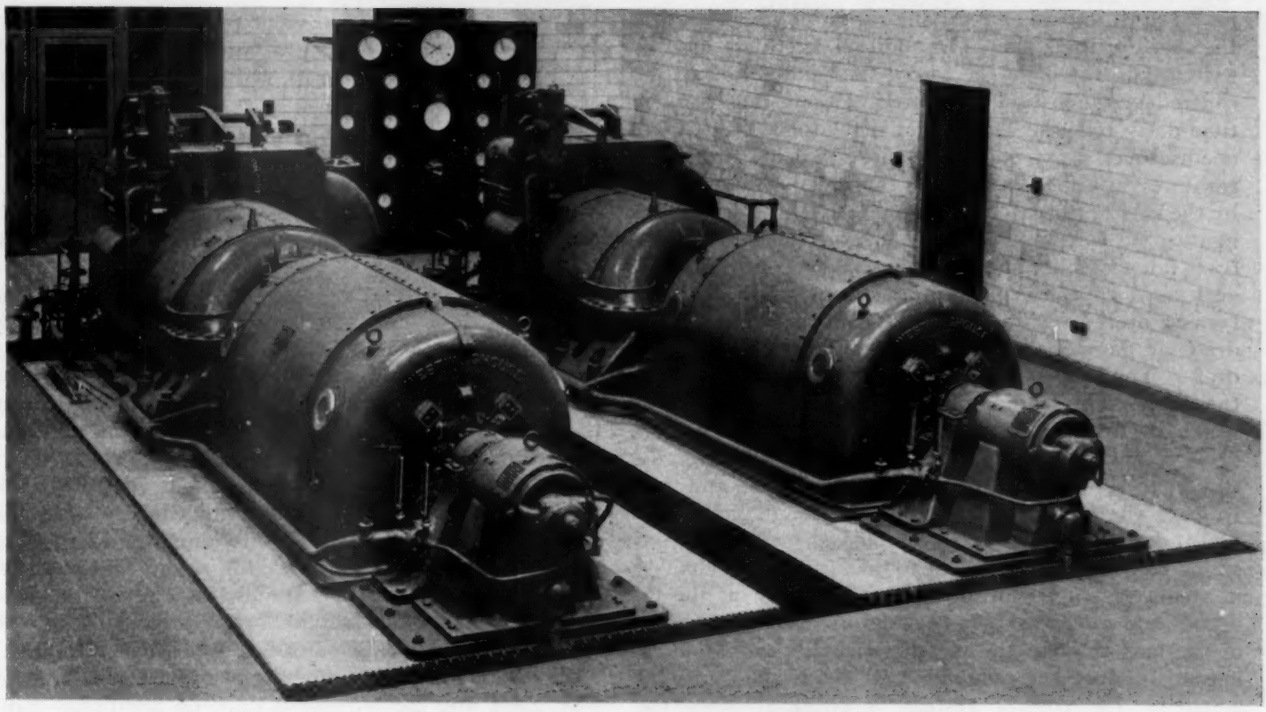

Fig. 12—Power for the University buildings is furnished by two 750 kw turbine generators

Fig. 13—Motor driving the forced-draft fan

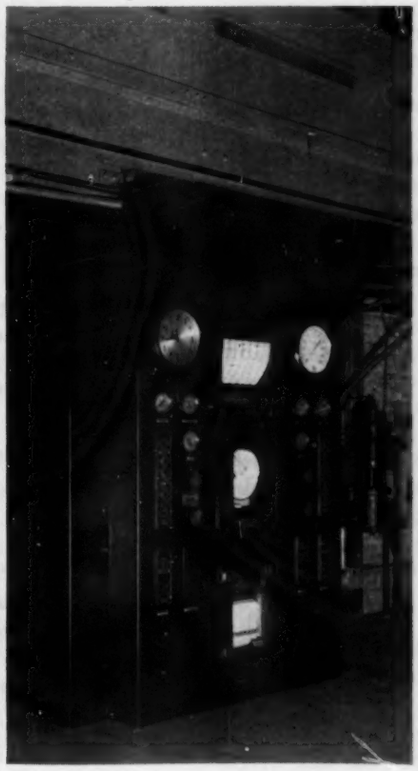

Fig. 14—Control and boiler instrument panel

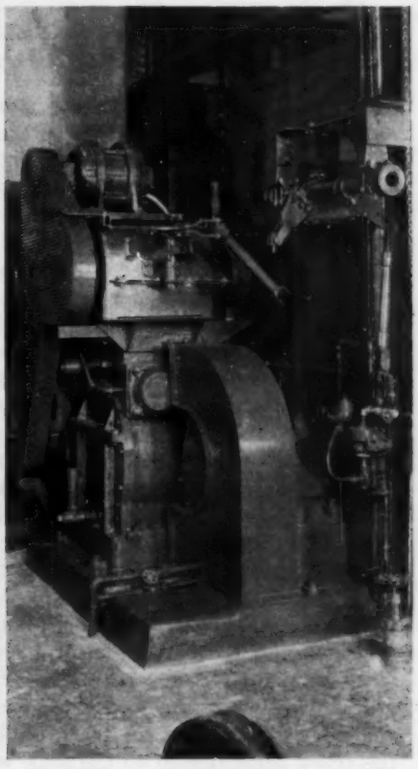

Fig. 15—Stoker drive through variable speed transmission

comprises a master regulator which receives its impulse from the steam header, a compensating relay, fuel and air ratio relay, loaded float controller on the induced-draft fan, balanced float controller connected with the forced-draft fan, and a receiving regulator which controls the speed of the stoker. In addition, there are mercoid switches operated by the forced- and induced-draft fan controllers which vary the speed of these fans through time delay relays. The master regulator is adjusted to operate over a five-pound pressure gradient, and steam pressure variations within this range are communicated by the master regulator to the compensating relay, which in turn varies the air pressure loading on the induced-draft fan controller and therefore the draft at the boiler outlet. A change in boiler outlet draft produces a new furnace draft which actuates the control on the forced-draft fan damper and re-establishes the original furnace draft. The compensating relay at the same time varies the air pressure loading on the fuel and air ratio relay which in turn varies the air pressure on the Reeves drive receiving regulator and changes the speed of the stoker, to supply more or less fuel as may be required. In case the changes in position of the induced- and forced-draft fan dampers, as established by the compensating relay, are not sufficient to take care of the changes in steam pressure, shifting control switches on the induced- and forced-draft fan regulators change the speed of the fans through the mercoid switches and time relays to produce the required draft conditions. Air for actuating the control system is obtained from the plant's compressed air system. An auxiliary air compressor is installed for use in case of failure of the plant air service.

On the control panel, shown in Fig. 14 are mounted, in addition to the combustion control equipment, the following:

A Duragauge for indicating steam pressure at the superheater outlet.

A six-point Bailey gage indicating forced- and induced drafts, furnace draft, boiler-outlet draft, superheater-outlet draft and pressure differential through the superheater.

A Bailey meter for recording steam and air flow, and stoker speed.

A Micromax for recording temperature of air entering and leaving the preheater, gas entering and leaving the preheater, feedwater entering the boiler, and steam leaving the superheater.

Near the control panel are also located a venturi meter for recording and indicating the amount of water fed to the boiler, and a Ranarex CO_2 indicator and recorder. A Philo multiple draft gage is located on the side of the boiler for indicating the pressures of air supplied to the several compartments of the stoker.

Lignite is delivered to the plant in trucks and is weighed on a Fairbanks platform scale located just outside the plant. A record of the gross weight is made automatically in the turbine room. After weighing, the truck is driven off the scale, the lignite unloaded and the truck again driven on the scale when the tare weight is recorded underneath the gross weight. In this way a record of the weight of lignite delivered to the plant is made without the aid of an attendant. The truck driver receives a signal from both a light and a bell when the scale has come to balance and a record of the weight is made. The scale and recording device are shown in Fig. 16.

The lignite is crushed to about $1^1/_2$ in. in size and is elevated into the overhead bunker within the boiler room from which it is discharged as required into a Link-Belt traveling weigh larry, weighed and delivered into the stoker hopper.

The ash is continuously discharged from the grate into an ash hopper having two discharge gates at the bottom, through which it is removed into cars and emptied into a skip hoist and elevated to an ash storage bin outside the boiler house. The ash removal system is illustrated in Fig. 8.

The steam generating unit was put into service in September 1933 and has been operating continuously since that time except for two short periods of inspection. The load on the unit has for a greater part of the time been light, due to a lack of heating load. During the past winter the maximum demand on the unit was approximately 50,000 lb of steam per hour for short periods while a minimum load of about 7000 lb steam per hour was carried for a time immediately after the unit first went into service. The unit was designed to carry a maximum load of 75,000 lb steam continuously. During light load period a fire about 6 in. in thickness is employed and the fuel is burned principally on the rear compartment of the stoker. When generating 30,000 to 50,000 lb steam per hour the fuel bed is 7 in. to 8 in. thick and the burning is done on additional compartments toward the front of the furnace. It is not found advisable to crush the fuel below about 1 in. in size, as too much crushing results in a high percentage of fines which produces a fuel bed too compact to permit of proper passage of air for combustion. By carrying the fuel bed well to the rear of the furnace and completing the burning on the extreme rear compartment of the stoker, there is always a long well-ignited fuel bed available to respond to sudden increases in steam demand.

An evaporative test of the unit was made in March of this year when generating steam at approximately 32,000 lb per hr. The fuel was weighed on the traveling weigh larry after the scale had been carefully calibrated, and the feedwater was weighed in tanks on platform scales. An ultimate analysis of a composite sample of lignite obtained during the test was made by the University of Texas the results of which are as follow:

Moisture	35.12 per cent
Carbon	41.76 " "
Hydrogen	3.52 " "
Sulphur	0.87 " "
Ash	8.26 " "
Nitrogen	0.80 " "
Oxygen	9.67 " "
	100.00 " "
Heating value as fired	7409 Btu

The evaporative efficiency obtained, together with the distribution of heat losses as calculated from the data obtained during the test, and from the foregoing ultimate analysis are shown in the following tabulation:

HEAT BALANCE

Combined efficiency of boiler and superheater, air preheater, furnace and stoker	77.6 per cent
Heat lost in dry chimney gases	6.9 " "
Heat lost due to moisture in fuel and to burning of hydrogen	9.6 " "
Heat lost in solid carbon in ash pit refuse	1.1 " "
Heat lost by radiation (assumed)	1.5 " "
Unmeasured losses	3.3 " "
	100.0 " "

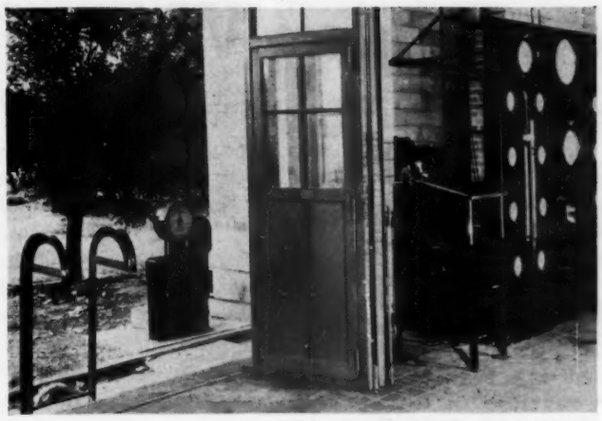

Fig. 16—Lignite is delivered in trucks and weighed on an automatic recording platform scale

The efficiency obtained on this test is about one per cent above that predicted by the equipment manufacturer at the rating at which the test was made.

The load characteristics imposed upon this steam generating system are comparatively severe. During the heating season peaks of the magnitude of 60,000 lb of steam per hour are experienced, but during the night period the demand frequently does not exceed 15,000 lb per hour for five or six consecutive hours. In spite of such circumstances, efficiencies obtained in daily operation have approached quite closely those achieved under test conditions. Plant records reveal that an average evaporation of 8.32 lb of equivalent evaporation per pound of dry lignite has been obtained throughout the past eight months of practically continuous operation.

The production costs for the month of March 1934 shown below may be regarded as typical.

COST PER UNIT OF STATION SENDOUT

Item	Per M lb equiv. evap.
Fuel	$0.192
Services consumed	0.012
Operation labor and supt.	0.024
Maintenance and repairs	0.008
Supplies	0.004
Total	$0.240
The cost of the lignite is:	
Cost of lignite mined and placed in cars	$0.85 per ton
Cost of lignite transportation	0.76 per ton
Cost of draying, crushing, feeding elevating, conveying of lignite and handling and disposing of refuse	0.50 per ton
Total cost	$2.11 per ton

During eight months of operation, interrupted only by two brief periods for inspection, not a single repair and very few adjustments have been made. The high availability factor, together with the good results shown by the unit since it was first put into service fully justify the selection and design of the equipment to supply the added requirements at the University of Texas, and demonstrate the ability of the traveling grate type of stoker to burn lignite.

Louis C. Madeira has been elected Executive Director of the Anthracite Institute. He was formerly vice president of Madeira, Hill & Co. one of the well-known independent anthracite companies.

Science Museum Appeals for Support

It appears from the annual report of the Trustees of the New York Museum of Science and Industry that sufficient funds are available to carry on to the end of the present calendar. The Museum which is housed in Daily News Building, 220 East 42nd Street, New York, has rapidly expanded in physical exhibits and educational service since it was started ten years ago and the total attendance last year reached over 234,000.

Financial support for carrying on the work of the Museum has been derived largely from the income of the estate of the late Henry R. Towne with some assistance from the Carnegie Foundation and the New York Foundation. A Surplus of $550,000 accumulated during the first few years has been expended in the preparation of permanent exhibits and during the past two or three years the income from the Towne estate has shrunk, as in the case of most other investments.

Under the terms of Mr. Towne's will, his trustees are directed to consider a number of factors in deciding upon the final disposition of the residuary estate, among which are the character, nature and extent of support from other sources that would insure the ultimate success of the Museum in fulfillment of the purposes set forth in the charter.

Because of these conditions the Trustees are at this time making an appeal for public support that will enable the Museum to construct a suitable and permanent building to house its present and future exhibits and carry on its educational program.

A.S.M.E. Nominates Officers

Nominations for officers of The American Society of Mechanical Engineers for 1935 were announced by the Nominating Committee during the Semi-Annual Meeting at Denver.

The nominees are:

President—R. E. Flanders, President, Jones & Lamson Machine Co., Springfield, Vt.

Vice Presidents—E.W. O'Brien, Editor, *Southern Power Journal*, Atlanta, Ga.; Jas. H. Herron, President, Jas. H. Herron Co., Cleveland, Ohio; H. R. Westcott, President, Westcott & Mapes, Inc., New Haven, Conn.

Managers—B. M. Brigman, Dean, Speed Scientific School, University of Louisville, Louisville, Ky.; Alfred Iddles, Vice President, United Engrs. & Constrs., Inc., Philadelphia, Pa.; J. W. Haney, Professor, University of Nebraska, Lincoln, Nebr.

The Trustees of Battelle Memorial Institute, Columbus, Ohio, announce the appointment of **Clyde E. Williams** as Director of the Institute, and **Dr. H. W. Gillett** as chief technical adviser. Announcement of these appointments comes with the news of an expansion program at Battelle. A greater range of research and development work within the Institute has been planned and, in addition, many new projects of outside sponsorship recently have been accepted.

Chlorination of Condenser Water*

By DON J. NEMETH, Results Engineer, The Detroit Edison Company

A review of development in the inhibition of algae and slime growths in circulating water by chlorination. It is demonstrated that this phenomenon is influenced by a variety of factors, the importance of which vary with local conditions. There is included a discussion of each phase of this process and its degree of success as indicated by the results obtained by users of this method of disinfection. Recommendations are given for solutions of various problems involved in the use of disinfectants in water supplies with the object of reducing unnecessary costs and promoting more economical condenser performance.

PRACTICALLY every phase of the control of organism growth in water supplies has shown some progress in fundamental concepts during recent years, and that phase relating to power-plant practice is no exception. Early experiments proving that disinfection actually had an inhibiting effect on organism growths did not result in demonstrating its commercial value in condenser operation. This fact was clearly a matter of balancing the ultimate value of the improved conditions against the cost of disinfectants which, at that time, were expensive. However, with operating costs favorably reduced, and definite results obtained by the use of disinfection, the process has been considered by practically every large power company where slime control in condensers is an important problem.

Composition of Condenser-Tube Deposits

The maintenance of clean condenser tubes and intake canals is important in all steam-generating plants operating such equipment. Difficulties arise due to a number of factors depending upon water and climatic conditions. The problem of condenser de-sliming is of such importance that it is rather surprising that only recently have investigations of the natural phenomena involved been made and put to practical use.

Condenser-tube surface deposits are generally complex organic and inorganic substances, the composition of which vary greatly in different sections. Slime deposits on tube surfaces reduce the rate of heat transfer and tend to lower the efficiency of the unit. Such fouling is the result of definite biological growths dependent upon the presence of certain organisms in the circulating water supply and temperature.

With seasonal prevalence, as generally encountered, it is probable that temperature is the predominating factor, particularly as to the time organisms start to grow and multiply. Once these growths are started they persist at other temperatures.

Gelatinous slime deposits are encountered most frequently. These adhere to the tube surfaces and are not removed by the velocities of the circulating water practical in condenser operation. The situation should be clarified by reconsidering the definition of slime and reviewing the theories of sterilization and oxidation.

Slime, as generally defined, is a conglomerate of inorganic matter such as clay, sand, silt and substances such as iron and aluminum hydroxide, oils, organic matter and aquatic plants, bound together by algae or bacterial growths. The character of slime deposits varies considerably in different sections and a definite classification is difficult. Slime formation consists of a minute interlacing of long tentacle growths, which accounts for its tenacity in adhering to the inner surfaces of condenser tubes. By its very nature slime reduces the rate of heat transfer, and when the deposits become sufficiently thick, the condenser efficiency becomes so impaired that it is necessary to shut down the unit and clean the tubes mechanically. Manual cleaning is not only disagreeable but eliminates unit availability for the complete cleaning period. The labor and outage are not only expensive, but this method results only in temporary tube cleanliness.

Characteristics of Water Supplies

Various growths are characteristic of most sources of circulating water supply. These growths consist of a variety of forms, some animal and others strictly vegetable. The quantity present and the resulting influence upon the quality of the water varies tremendously. The problem of vegetable growths has been recognized for some time, but in several power plants this problem has not been realized to the full extent. Laboratory analyses are carried out for both chemical and bacteriological constituents. The number of tests is quite limited, and as a result of this inadequate knowledge of conditions, difficulties have been experienced. There is little accurate scientific data available as to the nature and life cycle of aquatic growths occurring in circulating waters, and this problem readily offers an interesting and profitable field for biological study.

The term algae is commonly used to include all free floating plant growths, and is generally applied to all growths of microscopic organisms. The microscopic

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group are classified as chlorophyceae, schizophyceae, diatomaceae, cyanophyceae, phaeophyceae, rhodophyceae, xanthophyceae and fungi. The microscopic animal groups of most concern include protozoa, crustaceae, spongidea, rotifera and bryozoa. These general groups make their appearance under different conditions, and exert various effects upon the water supply. The factors that have a definite influence upon the magnitude of all aquatic growths are temperature, light, food supply, turbidity and various chemical constituents of the water. It is apparent that temperature is the factor predominating, and that organisms persist at all temperatures. The higher the temperature, the more rapid their development. Diatoms are normally growths in spring and fall at a temperature of approximately 50 F. Chlorophyceae are summer growths in the temperature range of 60 F to 80 F. Cyanophyceae are also summer growths at 70 F, or higher. Protozoa, the winter growth, exists at 32 F, or higher.

The algae and diatoms are forms of plankton which apparently perform the important part played by micro-organisms in changing inorganic to organic matter. The increased suspended matter raises the demand for disinfectants, sometimes to a very high value. All of these effects of plankton growths increase the cost of power-plant operation through heavier consumption of disinfectants.

Chlorination and Its Effects

The most effective point for the application of disinfecting agents varies with local conditions, with the character of the water, and with the particular method of disinfection used. Sufficient contact period, the proper dosage, and points of application of chlorination are important and must be carefully considered.

Chlorination is regarded as an element of biological control. It must be accorded first place as the most economical and practical means of suppressing organism growths in condenser operation. Particularly is this true if the circulating water has a high organic matter content which tends to foster intense bacterial activity. Chlorination, as recent practice has shown, is a cheap and satisfactory method of controlling slime fouling, and its advantages should not be overlooked. Reports from various users indicate that a gain in vacuum of 0.04 to 0.07 in. of mercury will pay for the cost of operation and maintenance of the system.

When a solution of chlorine, or hypochlorite, is added to a certain water supply, a variety of reactions may occur, depending upon the nature of the mineral and organic matter in the water. In general, the reactions may be classified and considered under three main headings: oxidation, direct chlorination and bactericidal action.

First, consider the characteristics of the oxidation reaction of organic and mineral matters. In the majority of waters, a greater part of the chlorine added is required to complete this reaction. The chlorine lost during this reaction is what is commonly known as chlorine absorbed. The reaction reaches approximately ninety per cent of completion very quickly. It is this reaction that determines the dosage required for effective sterilization, for the chlorine demand of the water must be satisfied before there will remain a definite excess to destroy the micro-organisms. It is advantageous to first receive definite information concerning the organism and chemical constituents of the circulating water in order that a proper dosage will be introduced.

Although the information available regarding the direct chlorination of the organic matter is limited, sufficient investigation has been made to prove that this does occur, and that chlorination of organic compounds is accomplished.

Finally, we have chlorination as possessing bactericidal action. Since chlorine is an active oxidizing agent and readily toxic in the inhibition of organism growth, a clear conception of the theory involved is essential for a comprehensive perception of its bactericidal phenomenon.

The theory that chlorine and chlorine compounds exert a direct toxic action on bacteria seems to be generally accepted as proved. A membrane forming the cell-envelope may be destroyed by the chlorine, or its derivatives may penetrate the membrane and produce changes that result in the death of the organisms. Chlorine treatment readily destroys biological growths, and consequently eliminates sliming by removing organisms that tend to bind organic and inorganic substances into a gelatinous mass. Although the sterilizing ability of chlorine and its compounds has been known for over a quarter of a century, yet its use in steam-plant operation has received its greatest impetus only during the past few years.

The early theories of the action of chlorine dealt with that of atomic, or nascent oxygen, and toxic effects. The atomic theory assumed a disinfectant action due to oxidation by means of atomic oxygen liberated by the decomposition of hypochlorous acid formed when chlorine is injected into water.

The oxidation theory of the effect of chlorine in producing the death of bacteria was, when primarily advanced, generally accepted, although evidence has been accumulating since that casts doubt upon it. It was pointed out that chlorine derivatives produced by the action of chlorine on amino acids and proteins were more likely to be the cause of the death of bacteria than a purely oxidizing action. Proteins present in sewage contain amino groups which may react with chlorine to form substituted chloramine containing the NCl group. When chlorine is added to sewage water there may occur a primary oxidation, and a secondary formation possessing a toxic action. Incidentally, this reaction is undoubtedly produced when chlorine is applied to urea which is present in polluted waters where the sewers empty into the water.

The oxidation theory was contradicted by results obtained with use of other active oxidizing agents which produced very low germicidal effects. It was further discovered that chloramines, compounds of chlorine, and not having the ability to liberate any oxygen, possessed much greater germicidal powers.

Considerable evidence shows that chlorine and chloramines exert a direct toxic effect upon organisms similar to the action of phenol. Bacterial destruction is believed to be a poisoning process wherein chlorine actually combines chemically with the protoplasm of the cell wall to produce a chlorine organic complex in the cell, readily destroying the organism growth. Such action is termed a cytallitic one, and is considered analogous to the death of animals in acids which carbonize the flesh. The

theory of toxicity of chlorine is considered the most advanced and generally accepted explanation of the sterilizing action of chlorine and chloramines.

The fact is fairly well established that chlorine or its compounds do not destroy the major content of algae in the water until a quantity has been supplied sufficient to combine with organic and inorganic matters present which have an equal avidity for chlorine.

Although chlorine gas is universally used to treat water supplies, yet a negligible amount of work has been done to determine the least amount of chlorine necessary to destroy known numbers of recognized species of organisms under fixed conditions that admit of comparison of relative resistance. It has been demonstrated that chlorine applied in sterilizing concentrations over short periods is as readily effective as continuous application. Resulting from this, de-sliming by the chlorination process developed into a very economical and practical control procedure in steam power-plant operation.

Quantity of chlorine, and frequency of application for proper de-sliming is a function of temperature, degree of organic pollution of the water supply and determined inorganic solids. The period of dosage, beyond being determined by the hydraulic conditions, should be such that there is approximately a three-minute residual chlorine contact in the condenser tubes. This minimum time is selected from a knowledge of the speed of sterilization. If, in addition, a large portion of the pollution of the water is a true organic mud, it may be necessary to use the oxidative reaction of chlorine, in which case the period may be increased from five to ten minutes to completely control fouling. Where the second effect is necessary, and organic matters are being chlorinated, the gelatinous structure is so changed in its nature, becoming more or less granular, that it is washed away from the surface of the tubes by the velocities of the water flowing through the condenser.

It has been noted that the chlorine will not penetrate below the surface of any thick deposits on the tube surfaces, and that difficulty was encountered where foreign matter stopped and formed a protective coating for the organisms. Also, chlorination generally does not prevent formation of scales on the tube surfaces or the deposition of solid substances. Data were obtained after tests were made determining the actual chlorine that was absorbed in the process of passing through the condenser tubes. It was found that the residual chlorine at the condenser outlet was practically identical with the residual chlorine admitted at the inlet. This showed that no appreciable amount of chlorine was absorbed in passing through the condenser. From this it was concluded that a proper dosage at the condenser inlet will insure thorough tube de-sliming.

The frequency of dosage is dependent upon the rate at which the organisms grow. A film of such thickness may be formed between dosages that the material is not easily or instantly penetrated by the chlorine. The length of the time of dosing will be more or less dependent upon the frequency, but is evidently more dependent upon the hydraulic condition. It is assumed that as the correct dosage is approached, the chlorine more readily attacks the organisms. The destruction is an indirect poisoning effect produced by chlorine since it is completed by the products which result from the constituents present in the water supply.

Waters which have not been subjected to a process of purification prior to disinfection will require a greater amount of the disinfecting agent and a longer period of actual contact. Experiments indicate that residual chlorine is more effective in distilled water than in the presence of organic and mineral substances. This explains the necessity for higher residual chlorine in the treatment of water possessing considerable amounts of organic and inorganic matter irrespective of the amount of chlorine necessary for the demand. The same condition is true of waters containing suspended matters; namely, turbidity in any appreciable quantity. In sections where turbidity is exceptionally high, consisting mostly of fine particles of granular sand, it has a constraining effect on algae growths in condenser tubes. This is due to the abrasive cleaning action of the sand which is carried through the tubes at the full velocity of the condensing water. The accompanying table contains analyses of a certain water supply, and the respective chlorine demands. This is illustrative of the effect of turbidity on chlorine demand where rains, storms and dredging are the definite causes of the increased turbidity value.

ANALYSES OF CERTAIN WATERS AND RESPECTIVE CHLORINE DEMANDS

	1	2	3	4
Chlorine demand—ppm	0.22	0.34	0.41	0.65
Suspended solids—ppm				
1. Turbidity	12.5	27.5	62.0	210.0
2. Total solids	134.2	151.4	167.7	183.3
3. Volatile matter	69.0	67.0	71.5	72.0
4. Fixed solids	78	97	121	138
Dissolved solids—ppm.				
A. Volatile matter	67	81	92	95
B. Fixed solids	70	75	84	87
1. Total solids	119	124	135	147
2. Silicon (SiO_2)	3.2	3.4	3.6	3.9
3. Total alkalinity	89.2	91.1	91.8	93.0
4. Normal CO_3	6.4	7.7	7.5	7.8

In order that there may be sufficient quantities of chlorine, a slight excess must be used over the amount required to react with the organic and inorganic constituents of the water. Frequent and accurate determinations on the residual chlorine maintained are required in order to use only enough chlorine to obtain the best results at a comparatively low cost. No specific dosage can be specified that would be definitely applicable to all conditions. However, for the most common organisms encountered, the usual amount of chlorine necessary, when using the intermittent method of application, is between 0.30 and 0.60 ppm residual chlorine above the water demand. The dosage varies, and in rare cases will be as high as 1.00 to 2.50 ppm. One part per million is equivalent to 8.3 lb per million gallons. The main factors which determine the dosage necessary to obtain the complete reaction are:

1. Temperature of the water supply.
2. Content of readily oxidizable organic matter.
3. Turbidity value.
4. Contact period.
5. Method of application of chlorine.

The amount of residual chlorine necessary to de-slime condenser tubes will vary greatly as it is a function of the character of the water and local operating conditions. By residual chlorine is meant chlorine in excess of the amount required for oxidation of the organic matter present.

Since it is the character of the water that determines the proper dosage to produce the desired results, it also has a decided influence upon the frequency and period of dosing. Experience has proved that by shorter pe-

riods, and more frequent dosing, less chlorine is actually used with as effective results. In highly polluted water the algae have a chance to multiply and grow between infrequent dosing periods. Sometimes a protective coating is formed on this gelatinous mass that will be inpenetrable to the ordinary amounts of residual chlorine. Frequent dosing will tend to eliminate this condition and yet not show any appreciable increase in the quantity of chlorine used, if the period is slightly decreased. In some instances, depending upon climatic conditions, chlorine is applied from once each half hour in summer to once in three to four hours in winter. In polluted water it would be more practical to dose from once in twenty minutes to once each half hour, corresponding to seasonal prevalence. Frequency of dosing is consequently more or less arbitrary, depending upon various conditions, invariably temperature.

Corrosive Possibilities of Chlorine in Solution

Chlorination of circulating water may be considered from two viewpoints; namely, prevention of tube surface fouling, and corrosive possibilities.

The primary object in using chlorine to treat circulating water is to reduce the cost of condenser tube cleaning, and to maintain the tubes in a greater state of cleanliness for a longer period than is possible with former cleaning methods. Increased rate of heat transfer resulting in a decrease of back pressure, and greater machine availability naturally follow a higher state of tube cleanliness.

Chlorine is one of the most powerful oxidizing agents known and, in highly concentrated solutions, it will influence corrosion. As the solution enters the condenser, there is encountered a reduction of pressure which may tend to flash chlorine out of solution. The conjecture is that the liberated oxidizing agent may cause a corrosive action and possibly lead to difficulties. It is generally conceded that when using a limestone solution fixing tank, there is practically no danger of the chlorine escaping as it is in a fairly stable solution prior to injection. From the standpoint of corrosive possibilities, the reports from sources using chlorine for other purposes than de-sliming of condenser tubes are not strictly comparable. In condenser operation the fixed chlorine solution is admitted far enough in advance to be thoroughly mixed before entering the condenser tubes, thereby eliminating the possibility of high concentrations in any particular area.

An experiment was made to determine the corrosive possibilities due to chlorine in the condenser tubes. In considering the number of hours per day of actual chlorine contact, an estimation was made as to the possibilities of condenser tube corrosion. It was found that for a period of one year a sample tube of known weight and volume decreased 0.0046 per cent per square inch in weight per year, it being immersed twenty-four hours per day in a concentrated chlorine solution of an average of 0.80 ppm residual chlorine. This is not strictly comparable as various other factors enter which would tend to lower this value to a great extent, and the fear of condenser-tube corrosion was readily banished.

Summary of the Effects of Chlorination

Summarizing the progress of chlorination, reports have definitely shown the following:

1. The net savings for one year due to chlorination of condensing water have exceeded one-half the total cost of all equipment, auxiliaries and labor charges, even in its experimental stage.
2. A decrease of 0.20 to 0.80 in. of mercury in back pressure was obtained.
3. Considerable decrease was noted in the circulating, and general service water pump power.
4. Less general service water required for heat transfer apparatus; namely, water-cooled transformers, oil coolers, generator air coolers, etc.
5. Elimination of all outage of apparatus for condenser cleaning.
6. Increase of unit availability with a constant clean condenser back pressure.

The Ammonia-Chlorine Treatment

Use of the ammonia-chlorine process in the treatment of municipal water supplies has become an established practice. The chief object in its industrial application is its effectiveness in the prevention of algae and slime formation. When a dilute solution of ammonia is added to a chlorine solution the result is a very toxic compound, namely, chloramine. It is in this connection that the ammonia-chlorine process is effective in prevention of slime formation in condenser tube surfaces.

Chloramines are products formed by the interaction of the ammonia and chlorine in such proportions that either one or two hydrogen atoms of the ammonia molecule are replaced by the chlorine atom. The principal reason for the decided interest in chloramines is their high germicidal value. Disinfectants are generally standardized against carbolic acid to determine their phenol coefficient. It was found that chlorine gas has a phenol coefficient of 2.20 when applied alone, but when ammonia was previously introduced the coefficient was 6.40. The combination, therefore, is practically three times more bactericidal than chlorine alone.

The application of ammonia is similar to that of chlorine, except that an ammoniator is used instead of a chlorinator. The general method of practice is to introduce the anhydrous ammonia first, sufficiently in advance of the chlorine solution so that it will be thoroughly distributed in the water before reaching the point of the chlorine solution application.

The actual dosage of the ammonia-chlorine to be used cannot be specifically stated as this factor is best determined under the particular operating conditions. However, it has been determined by actual practice that for general use, the average ratio of three parts of chlorine to two parts ammonia give satisfactory results. In actual operation the amounts used would be in ratio of 0.45 ppm of chlorine to 0.30 ppm ammonia, this value being governed by the chlorine demand of the water supply.

Ortho-Tolidine Test for Chlorine Residual

A reagent employed in detection and estimation of residual chlorine content cannot be used entirely in a specific test for chlorine as it is involved in similar reactions with other constituents in the water. Extreme care must be exercised in interpreting results obtained by its use. Substances such as manganese, nitrates, chlorates, organic coloring matter and ferric compounds in large quantities, are examples of interfering constitu-

ents of the water, and must be considered in evaluating the results. A more definite conclusion as to the practicability of the reagent for this specific use can be arrived at only by actual laboratory tests, and by determinations of the various involved reactions.

Ortho-tolidine is dimethyl benzidine, having a melting point of 264 F, and is slightly soluble in water. It is an amine and dissolves readily in acid, forming the water soluble salt of the base. The hydrochlorides react with minute amounts of free chlorine and of hypochlorites to produce solutions of a yellow color. Oxidizing agents produce similar coloration when treated with the hydrochloric acid solution of the reagent. A study was made to investigate whether this color reaction is due to the chlorination of the amine or to oxidation.

Because the hydrochloric acid of the reagent could produce free chlorine when reacting with oxidizing agents, there is ground for belief that color production may be due entirely to the entrance of chlorine atoms into the ortho-tolidine rings. Also, as a water solution of chlorine is an oxidizing agent, this solution, in common with hypochlorites and other oxidizing agents, produces the coloration reaction by the process of oxidation.

Temperature is an important factor in determining the correct coloration of a sample after the reagent has been added. At 50 F, or higher, a ten-minute contact period must be allowed for a sample solution. Below this a ten- to thirty-minute period is recommended for completion of the coloration.

Hydrogen-Ion Concentration

Possibility of the use of hydrogen-ion concentration in the control of chlorination of organisms has been a subject of recent discussion. Previously its determination and evaluation has been more or less a chemical practice in various water analyses without any conception of the practical aspects involved. While the hydrogen-ion concentration is quite important, it is not the sole determinant. The influence of the reaction of the water itself on the disinfecting action of chlorine has received little consideration. It has been known that chlorine behaves differently in the presence of alkalies and acids. It was pointed out that hypochlorites should be better oxidizing agents in an acid than in an alkaline solution. Tests showed that 0.02 ppm of chlorine at a pH of 6.0 was as effective as 0.20 ppm of chlorine at a pH of 9.0. It was made clear that a shift from an acid to an alkaline reaction caused a marked change in the germicidal action of chlorine. Experiments proved that the necessary destroying dose of chlorine is dependent upon the reaction of the water to be disinfected. As the pH value of the water increases, the amount of chlorine must also increase, if the disinfecting time is to be kept constant. It is this reaction of the water which influences the germicidal activity of chlorine. It has been reported that excess hydrate alkalinity has a restraining influence upon microscopic organisms. Increasing alkalinity causes a decreased germicidal activity, and an increasing period for death of the organisms.

Chlorine Tanks and Auxiliaries

Storage of cylinders containing chlorine gas under pressure should be in a moderately cool place. It is further advisable to partly submerge the tanks in a water bath, the temperature of which can be controlled to give the desired chlorine pressure. Above the containers and chlorinators should be installed a sprinkling system with an abundant water supply to render the gas vapors harmless with finely distributed water spray. The operating valve on this system must be readily accessible in case of an emergency.

The tanks and piping should be protected from direct sunlight and from excess heat in order to prevent the variations in temperature and pressure. Supply tanks, and apparatus for the conveyance of the gas, should be installed in a room maintained at not less than 60 F, since the conversion of the liquid chlorine to gaseous form requires heat which, of course, is drawn from the container in which the liquid is enclosed. The more rapid the evaporation of liquid chlorine, the greater the lowering of its temperature, producing what is known as chlorine ice.

Chlorine, in the containers, is kept in liquid form by the pressure which is relieved when the valve is opened on the gas discharge line. This reduction of pressure permits the liquid to transform to a gas and it is supplied in this form to the chlorinators. The liquid state is maintained at comparatively low pressure, in cold temperatures as low as 35 lb per sq in. When the discharge valve is opened the chlorine passes out as a gas, lowering the temperature in the container. When this gas is drawn off too rapidly, there will form a heavy frost around the valve and on the exterior of the container. The small opening in the reducing valve will freeze, inhibit the flow of gas, and in time completely clog the line. If the tanks are at a higher temperature with the chlorine at a correspondingly high pressure, when this high-pressure gas passes into a colder pipe line, then to a cooler area in the chlorinator, due to the high pressure, the gas will reliquefy and produce chlorine ice. In order to eliminate chlorine ice at the float valve within the chlorinator jar, a water heater must be installed on the tray water supply line and regulated to maintain a temperature of 50 F, or higher.

In the care of valves and connections, immediate attention should be given to the smallest leak, not only as a safety factor, but to eliminate tube and valve corrosion. A bottle containing a solution of ammonium hydroxide is to be provided for chlorine leakage detection. Visible white gaseous vapor results from the combination of chlorine gas with the ammonia vapor. Operators must acquaint themselves with the use of the chlorine gas masks that are to be provided for cases of emergency. These must be installed in readily accessible places.

Chlorination Equipment

The chlorinating equipment used in condensing-water sterilization is relatively simple in design. The Wallace & Tiernan intermittent chlorination apparatus is arranged to accomplish the dosing of circulating water supply with chlorine requiring automatic and intermittent application of the chlorine solution. Operation of the apparatus requires very little detailed supervision or attention. The care and regulation is dependent upon changes of temperature, circulating water quantity, and the demand of the water.

In the limestone reservoir type, the chlorine gas is discharged from the supply tanks to the vacuum type solution feed chlorinator, which is the control device for

accurately measuring the chlorine consumption per unit of time. The gas passes through the chlorine reducing valve into the transparent bell jar, through the glass orifice meter, then through the adjustable head tube within the orifice meter, to the injector throat, where it is mixed with the general service water flowing through the aspirator. Then the chlorine solution is discharged from the chlorinator, by means of a rubber hose, to a large tank containing crushed limestone. The chlorinator is entirely hydraulically operated, and its regulation is obtained automatically by means of a pressure-reducing valve controlling the quantity of water supplied to the chlorinator.

The limestone in the tank acts as a "fixing" agent for the chlorine solution. The tank serves as a storage reservoir from which the fixed chlorine solution is to be pumped into the condensing water supply at predetermined intervals depending upon the period of dosing.

A program clock automatically controls the dosing periods, the interval and amount of dosage is varied, and is a function of the existing conditions. At prearranged intervals the solution pumps are operated to pump the stored solution from the tank to the circulating water canals at a point where it will be sufficiently mixed before entering the condenser. When the operation of the apparatus is balanced, the amount of solution supplied by the chlorinator, which operates continuously, will balance the amount pumped from the tank by the solution pump during the specified period of dosing.

Automatic Syphoning Process

A system of chlorination by the automatic syphoning process, which eliminates practically all electrical apparatus, is under consideration but has not reached any definite experimental stage. Further development of this system will readily eliminate a considerable number of difficulties experienced with the present system along with a large percentage of decrease in the cost of installation.

The process is accomplished by a periodic syphoning system which is regulated by the amount of water introduced into the solution tank. The accuracy is dependent upon the uniformity of the pressure of the water flowing through the main reducing valve at the chlorinator and the auxiliary reducing valve on the make-up line. The period is adjusted by means of a variable orifice installed on the solution discharge pipe. The frequency is regulated by means of the reducing valves on the general service water inlet line. Once the system is properly adjusted for the desired application of the disinfectant, there is practically no further requirement for attention or supervision. The overflowing of solution tanks is entirely eliminated, where formerly the corrosive action of the over-flowed solution caused considerable damage to equipment along with unpleasant conditions for operators.

This particular method is more or less adaptable to operation in smaller plants where the initial cost is the impediment for the installation of this type of chlorination equipment.

Conclusion

From the preceding discussion, it is evident that the type of equipment used to introduce chlorine into the circulating water has a bearing upon its practicability in operating automatically and efficiently. It is generally conceded that the intermittent process has proved the most economical as well as practical method. With the cost of chlorine being reduced materially, and the ultimate effects derived from its use, chlorination has become a valuable asset in steam-power generation. It has been proved adaptable to condenser operation, and the gain in vacuum makes it desirable and profitable.

In conclusion, it may be further noted that results obtained in practical condenser operation have demonstrated the ultimate value of the chlorination process from the standpoint of a profitable method of controlling condenser tube fouling where slime and algae growths are the fouling substances. Although the biological considerations are more or less in a controversial state, yet the underlying facts have been established by continued research carried on by companies using this process. A step toward determination of the least amount of disinfectant required for complete de-sliming is an important phase of the problem that might receive some attention.

When this method is properly applied, and controlled, there is indication that the results obtained will be most satisfactory, both in costs and advantages in comparison with former methods of condenser slime control.

A few references to this subject will be found in the appended bibliography.

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Hartford Electric Light Co. Receives Coffin Award

The Hartford Electric Light Company, one of the pioneer electric utilities of America, received the annual award for 1933 of the Charles A. Coffin Foundation, established by the General Electric Company. The presentation of the award was made June 6, 1934, at Atlantic City to Samuel Ferguson, president of the winning company, during the annual convention of the Edison Electric Institute.

The award comprises the Charles A. Coffin gold medal, a certificate, and a check for $1,000 to be deposited in the treasury of the utility's Employees' Welfare Association. Determination of the winner of the award was made by a committee of judges consisting of George B. Cortelyou, president of the Edison Electric Institute; Dr. Karl T. Compton, president of Massachusetts Institute of Technology; and Frank W. Smith, chairman of the prize award committee of the Edison Electric Institute.

The record of the Hartford Electric Light Company for 1933, upon which the award is based, is declared to be most impressive. In a depression year this company reduced the rates to its customers, at the same time improving the quality of its service; maintained its full force of employees at the 1929 level and without reductions in pay; paid full dividends to its stockholders, setting aside a moderate surplus, but larger than the previous year, and maintained a city-wide good will with its public.

Interpretation of Creep Tests*

If it were possible to conduct creep tests under exact simulation of working conditions and over a period of time comparable with the expected service life, there would be little difficulty in interpreting the results. In addition to the prohibitive cost of such a procedure, experience has shown that the materials would be obsolete long before the completion of such a testing program. As a result, creep tests must be extrapolated if they are to have design value. This paper discusses the fundamental nature of the creep curve and the probable effect upon it of strain-hardening, annealing, age-hardening and other phenomena associated with the long exposure of complex alloys to stress at elevated temperatures. The possible effects of "creep-recovery" are mentioned. Examples are given to show how, under suitable conditions, published creep data may be correlated.

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IT IS a peculiar fact, that those most familiar with high-temperature testing and with the vagaries of complex alloys under stress at elevated temperatures are somewhat reticent about their interpretation of creep tests. They foresee the possible effects of slight changes in the many variables involved during the tests and in subsequent service, and they hesitate to predict the performance of a new alloy, especially if the allowable deformation must be held within close limits.

We have, on the one hand, a demand for reliable data which can be used to support the progress of design toward higher temperatures; on the other hand, we find available materials exhibiting strange peculiarities which make it difficult to evaluate them by any simple method. The designer specifies an estimated time-temperature cycle, desired service life and limiting deformation, and asks what stress he may use safely. It is this apparently simple question which has stimulated creep testing for over ten years. The answer is complete only if it gives the allowable stress and cost per pound of all available materials, since the economic side of the problem also must be considered. It is obvious that any change in the specified variables must have its effect upon the allowable stress. To satisfy the need for design information it is necessary, therefore, to establish for each material the relations among the four variables—stress, strain, time, and temperature covering the desired range for each variable.

Of the various methods of interpretation that have been proposed, the simplest combines strain and time into creep rate. For a single temperature the logarithm of this rate is then plotted against the stress or the logarithm of the stress giving an approximately straight line and an implied relation expressed by an exponential or power function. These curves permit easy interpolation between test stresses and extrapolation to lower stresses and they have been widely used because of their convenience. The fact that some authorities use a power function while others use an exponential function to express the relation between stress and creep rate at constant temperature shows a lack of data to decide which is correct. Either method has a decided disadvantage in that logarithmic plotting prevents use of the assumption that creep rate is zero when stress is zero. The inference, also, that a definite creep rate may be associated with each combination of stress and temperature is open to criticism. Furthermore, the use of a creep rate in this way suggests no limitation upon the variable, time. In other words, it is assumed that the creep curve is a straight line through the origin and that it may be prolonged indefinitely. It is difficult to reconcile these assumptions with actual creep data. Since our present methods of analysis lead to doubtful conclusions, it is desirable to make a new survey of the problem in the light of available data.

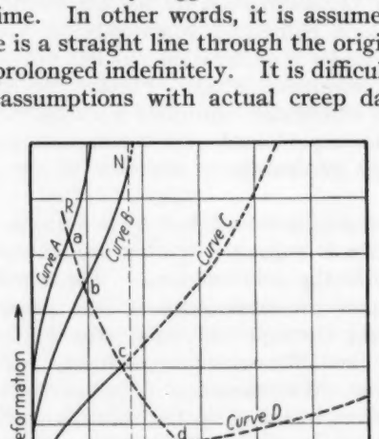

Fig. 1—Creep curves for several stresses at constant temperature

Interpolation and Extrapolation of Creep Curves

In Fig. 1, curve *A* represents a typical creep curve as obtained at constant temperature and a relatively high stress. An elastic deformation results from the application of the load after which creep proceeds at a gradu-

* Excerpts from a paper presented at the Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 25–29, 1934.

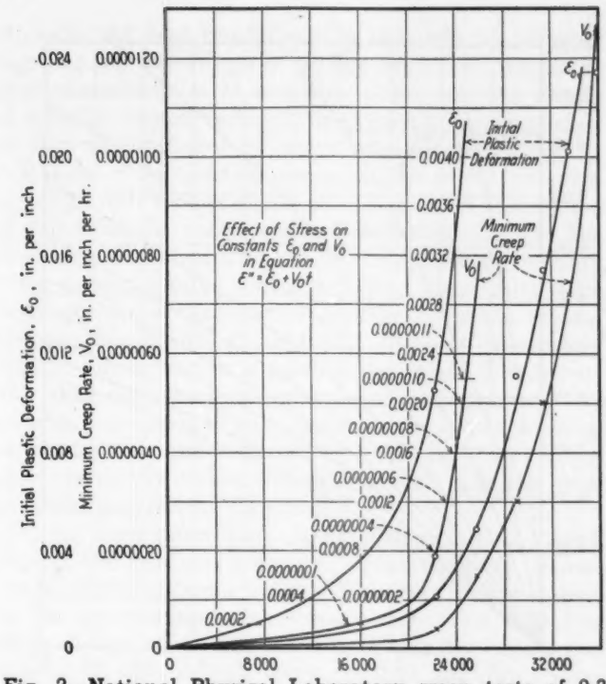

Fig. 2—National Physical Laboratory creep tests of 0.30 per cent carbon cast steel

Annealed 800 C (1470 F), 19 hr. Rough machined. Annealed 550 C (1020 F), 6 hr. Tested at 400 C (750 F). (H. J. Tapsell and A. E. Johnson, Special Report No. 17, Department of Scientific and Industrial Research (1931)).

ally diminishing rate. At *a* an inflection occurs after which the creep rate increases until the test specimen breaks. Curve *B* is similar for a lower stress, the longer time to produce fracture resulting from lower creep rates. As the stress is further reduced, similar tests on different specimens give curves *C*, *D*, *E*, *F* and *G*. The locus of points of inflection, *RS*, is not well known because tests are seldom carried beyond the line *MN*. Available data indicate, however, that the change from a decreasing to an increasing creep rate occurs at a gradually diminishing value of total deformation represented by the points, *a*, *b*, *c*, *d* and *e*. To determine the inflection points for curves *F* and *G* would require tests of extremely long duration. As the stress decreases, the creep curve is essentially a straight line for a progressively longer period of time as it approaches its inflection point. Theoretically, the rate is continuously decreasing but actually, the line may be considered straight without serious error. The nature of the curves is such that we may expect the increase of rate to be equally slow after the inflection has been passed. Since actual working stresses are usually below curve *G*, the assumption that the creep curve approaches a straight line is sufficiently accurate for many purposes. In no case, however, does the straight line pass through the origin. Any analysis of families of creep curves must make some allowance for the more rapid creep rate in the initial stage.

Creep of Pure Metals—Strain Hardening and Annealing

To simplify the discussion of creep phenomena, let us consider that the curves of Fig. 1 represent tests of a pure metal, thus eliminating any possibility of solid solution or precipitation of constituents. For such a material, the decreasing creep rate in the first stage may be attributed to strain hardening which results from the gradually increasing deformation. If it were not for the softening effect of temperature upon strain-hardened material, this might continue indefinitely as the creep rate approached zero.

Studies of the effect of temperature upon strain-hardened material show that the time required to produce softening at a given temperature decreases as the amount of deformation increases. This softening tends to increase the creep rate.

In this ideal case, we have two opposing forces, one decreasing and the other increasing in magnitude as time goes on. It should be noted that separate studies of both the strain-hardening and the annealing effects reveal no discontinuities and a creep curve representing the net effect of the two phenomena must have a point of inflection as shown in Fig. 1. In the absence of a more complete explanation, we may say that the form of the typical creep curve is greatly influenced if not entirely controlled by strain-hardening and annealing during the progress of the test. If practical considerations restrict our tests to that portion of the curves lying to the left of line *MN*, we may use the reasoning outlined above to supply the dotted portions of the curves representing the longer times found in service. Without some simplification of this kind it would be practically impossible to analyze the very complicated conditions actually existing and make allowance for necessary departures from the assumed simple relations. It must not be inferred, however, that these departures are negligible.

Creep of Complex Alloys—Structural Changes

Recent tests of complex alloys have revealed many peculiarities. For example, impact tests before and after creep tests frequently show marked embrittlement of the material due to long exposure to stress at high temperature. This, in itself, may be enough to prevent the use of the material where good ductility is considered essential. For the purpose of this discussion, it is more important to consider the fact that the data obtained from the creep tests must have been influenced by the gradual structural change within the material. The propriety of extrapolating such a test to cover a long service life is extremely questionable.

Another example recently came to the attention of the author in which a test showed continuous negative

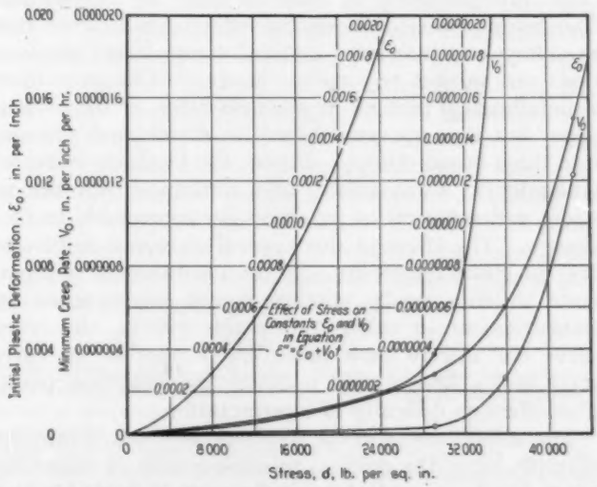

Fig. 3—National Physical Laboratory creep tests of 0.39 per cent carbon forged steel

Furnace cooled. Rough machined. Annealed 550 C (1020 F). Tested at 400 C (750 F). (H. J. Tapsell and A. E. Johnson, Special Report No. 17, Department of Scientific and Industrial Research (1931)).

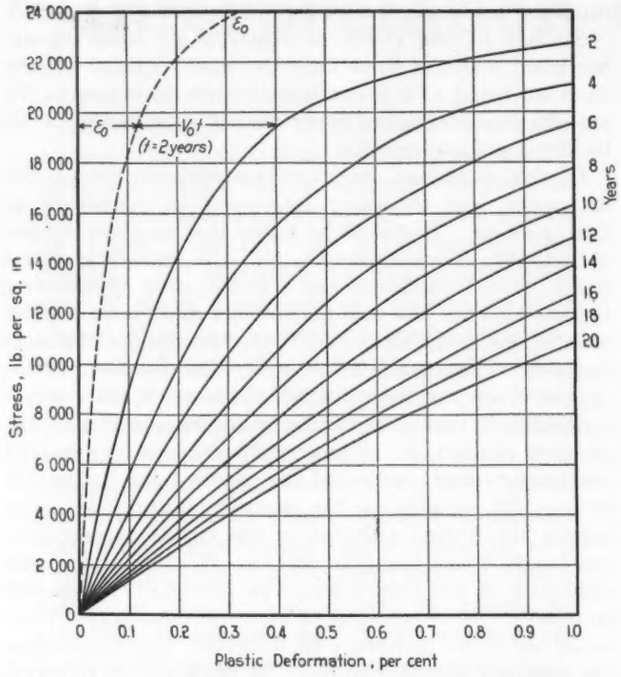

Fig. 4—Stress-strain-time relations at constant temperature

0.30 per cent carbon cast steel—400 C (750 F). Based on creep tests of H. J. Tapsell and A. E. Johnson, Special Report No. 17, Department of Scientific and Industrial Research (1931).

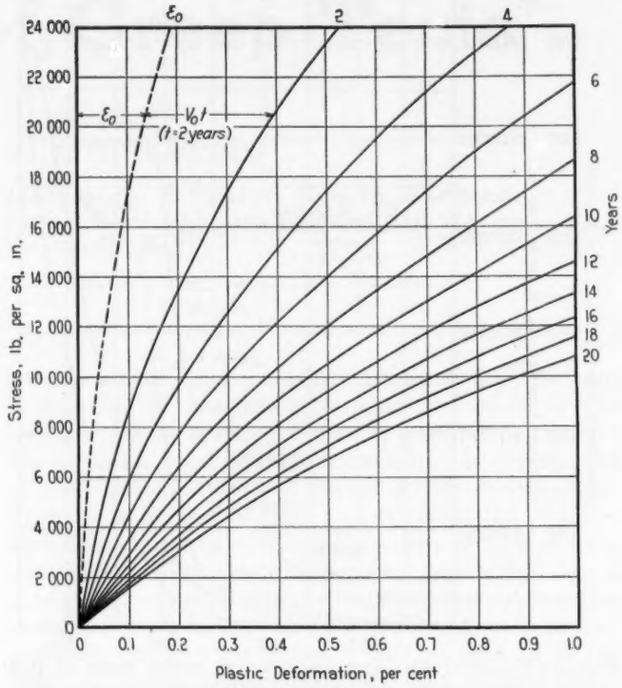

Fig. 5—Stress-strain-time relations at constant temperature

0.39 per cent carbon forged steel—400 C (750 F). Based on creep tests of H. J. Tapsell and A. E. Johnson, Special Report No. 17, Department of Scientific and Industrial Research (1931).

creep over a period of 2500 hr. This can only be explained by a structural change causing a decrease of volume which completely masked the natural creep in the direction of the applied stress. One advantage of a test of this kind lies in its warning to investigate structural stability. A more dangerous case is the one in which structural change decreases all the creep rates in a series of tests without showing negative creep. Special precautions are necessary at all times to avoid this possibility if the data are to be used for design purposes.

It is apparent that creep tests are vitally affected by structural changes during the progress of the test and their interpretation is affected also by subsequent changes in service. Recent investigations indicate that the alloys recommended for high-temperature applications are subject to similar changes. This introduces a metallurgical problem beyond the scope of the present paper but it is convenient here to divide such changes into three broad classes. In one, the hardness increases gradually to a maximum, and continued exposure to stress and temperature produces no appreciable further change. The effect of this type of change is similar to that of strain-hardening. If the condition of approximate stability finally reached is not accompanied by embrittlement or other undesirable effects, the creep curve will merely show lower creep rates in the early stage and a longer time to reach the inflection point. This offers no difficulty of interpretation.

The second works in the opposite direction, a familiar example being the gradual spheroidization of cementite which has been studied by Bailey and Roberts (*1*) and others. If a long life is desired and the allowable deformation is small, the stable condition may be obtained prior to the test by suitable heat treatment, so as to make the extrapolation of the creep curves more reliable. It is evident, however, that it may be possible to secure a long service life before the spheroidization affects the strength seriously. This is equivalent to an increase in the annealing effect mentioned for a pure metal. Careful study of an individual case should allow the use of a higher stress than would be permitted in following hard and fast rules.

The third type of age-hardening involves a gradual increase to a maximum followed by a similar decrease to a condition of approximate stability. Alloys showing this phenomenon during the creep test give results particularly difficult to interpret. This does not prevent their use, however, because it is usually possible to apply a stabilizing treatment prior to the creep tests to bring them into approximate equilibrium with test and service conditions. Any attempt to take advantage of a temporary improvement in creep properties due to this type of age-hardening should be avoided, if allowable deformation is the criterion of safety.

From this it is evident that the interpretation of creep tests requires some familiarity with the characteristics of the materials and such auxiliary tests or preliminary heat treatment, or both, as may be found necessary to justify extrapolation. If a family of creep curves is interpreted without considering the possibility of lack of stability, the results may be decidedly misleading.

It has been suggested that the entire responsibility of interpretation be placed upon the designer. This imposes a serious additional burden upon the factor of safety and it may lead to the elimination of desirable alloys as a result of improper interpretation and application. It would seem fairer to all concerned if the evaluation of materials resulted from the closest cooperation between the metallurgist and testing engineer. It is

obvious that best results can be obtained by bringing together full knowledge of service conditions, metallurgical characteristics of available alloys and the results of suitably chosen tests. This cannot be accomplished by a mere tabulation of creep rates for design use.

It is out of the question to suggest that further progress in design wait for the better test data which may be expected from the use of the new test code (*2*). In the meantime, the maximum use must be made of the data from various sources now available. These data have been acquired at considerable expense in various laboratories in this country and abroad. In many cases, fairly reliable interpretation is possible; in others it is inevitable that misleading conclusions may be reached. By suitable correlation of data, tests notably out of line may be weeded out and replaced by a few carefully chosen check tests. In this survey nothing can take the place of sound engineering judgment.

It has been stated that the designer requires a knowledge of the relations among the four variables—stress, strain, time and temperature. The first two are covered in the conventional short-time tension test, the first three in the creep test and the fourth by conducting short-time tension and creep tests at suitably chosen temperatures. Under proper control, creep recovery offers an opportunity to increase the working stress in intermittent stress applications, but it is obvious that this advantage must be used advisedly.

In a recent paper (*3*) the author suggested a method of attack upon the miscellaneous creep data now available. The main purpose of such a survey will be to reduce all data to a comparable form to allow correlation.

Proposed Method for Interpreting and Correlating Creep Data

To show the possibilities of such a method, use will be made of creep data in a report by H. J. Tapsell and A.E. Johnson (*4*). The work was done at the National Physical Laboratory under the most favorable conditions for securing reliable data. The two materials were carefully heat treated prior to the tests to ensure stability. For the purpose of this analysis, the data in Table I have been taken from Tables II, III and IV of their report.

Following the method previously explained, each creep curve may be replaced, for the purpose of extrapolation, by a straight line having the equation:

$$\epsilon'' = \epsilon_o'' + v_o t$$

where ϵ'' = final plastic strain or creep in inches per inch,
ϵ_o'' = initial plastic strain in inches per inch,
v_o = minimum creep rate in inches per inch per hour and
t = time in hours.

Since the values of ϵ_o'' and v_o are functions of the applied stress, they may be so plotted as shown in Figs. 2 and 3. It would be very desirable to have tests at lower stresses but in their absence it is permissible to extend the curves to the origin. To facilitate the reading of values of the two variables at low stresses, each curve has been replotted to a larger scale on the same sheet with values indicated along the curves.

By selecting values of ϵ_o'' and v_o from these curves for the desired range of stresses, it is possible to compute the creep at the end of various time intervals. This permits the plotting of the estimated creep at the end of 2 years, 4 years, etc., in a form which represents the effect of time upon the stress-strain curves as shown in Figs. 4 and 5.

TABLE I—CREEP DATA ON CAST AND FORGED STEEL (TAPSELL AND JOHNSON)

Stress, lb per sq in.	Final Strain, ϵ, in. per inch	Time, t, hr	Minimum Creep Rate, v_o, in. per inch per hr	ϵ_{ol}, in. per inch	Initial Elastic Plus Plastic Strain, $\epsilon_o = \epsilon - \epsilon_{ol}$, in. per inch	Elastic Strain, ϵ' in. per inch	Initial Plastic Strain ϵ_o'' in. per inch
0.30 Per Cent Carbon Cast Steel at 400 C (750 F)							
35,840	0.0368	960	0.0000125	0.01200	0.0248	0.0014	0.0234
33,600	0.0267	720	0.0000072	0.005184	0.0215	0.0013	0.0202
31,360	0.0209	864	0.0000050	0.004320	0.0166	0.0012	0.0154
29,120	0.0163	1368	0.0000030	0.004104	0.0122	0.0011	0.0111
25,760	0.0072	912	0.00000148	0.001350	0.00585	0.0010	0.00485
22,400	0.0036	1656	0.000000375	0.000621	0.00298	0.00087	0.00211
0.39 Per Cent Carbon Forged Steel at 400 C (750 F)							
42,560	0.0229	504	0.00001230	0.0061992	0.0167	0.00174	0.01496
35,840	0.0104	1080	0.00000268	0.0028944	0.0075	0.00146	0.00604
29,120	0.0055	4128	0.000000375	0.0015480	0.0040	0.00119	0.00281

These charts give the designer the desired information as to the relations among the variables stress, strain and time for the given temperature. They assume that inflections will not occur within the service life of the material at deformations less than one per cent and that the creep curve at low stresses may be extrapolated along the final tangent. They take into account the initial plastic deformation obtained by extrapolating the final tangent to zero time.

If, for example, the designer wishes to know what stress he may use to keep the plastic deformation within the limit of 0.5 per cent in 10 years, he reads from Fig. 4 for the cast steel a stress of 10,700 lb per sq in. and from Fig. 5 for the forged steel a stress of 10,500 lb per sq in.

This method of comparison is offered as a tentative suggestion. The difficulty in making corrections for the effects of changes in the many variables involved is fully realized. If, however, all available data were reduced to this form and compared, inconsistencies would be revealed and the reliability of all the data improved by a few check tests. It is only by correlation of this kind that the maximum value may be obtained.

Conclusions

In conclusion, it has been shown that creep tests have very definite requirements and limitations. While objections may be raised to their extrapolation, they are practically useless to the designer unless extrapolated to times representing the expected life in service. Some of the present methods of interpretation have been discussed with particular reference to the importance of structural stability in service. The use of creep rate alone to evaluate a material for a given stress and temperature has been shown to be incomplete. Finally, a method of interpretation has been suggested which offers some advantages over those previously used and indicates a possibility of correlating and making use of the large mass of creep data now available.

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Is Engineering Overcrowded?*

By DR. HARVEY N. DAVIS
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Although there appears to be a surplus of technically trained men at present, due to a large shrinkage in the capital goods industries, Doctor Davis cites statistics and studies to show that this condition is only temporary and that by 1937 the engineering colleges will be graduating only about two-thirds the requirements. Based upon the growth of certain major industries in the past twenty-five years, which have absorbed large numbers of engineers, the prediction is made that industrial research, new processes, rehabilitation of existing industries and management will create a heavy demand for men with technical training in the near future.

IS ENGINEERING overcrowded? Everybody seems to think so, and, of course, at the moment, it is. So is bricklaying, and doctoring and nearly every other occupation or profession. Indeed, at the moment, engineering is probably more overcrowded than are most of the professions. This is because many engineers are normally occupied with designing and making producer's goods. It is well known that in times of severe depression, when the production of consumer goods drops to perhaps three-quarters of normal output, the production of capital goods may drop to even as little as one-tenth of normal output. For this reason, engineers and architects have undoubtedly had a much harder time these last few years than have many other groups, and unemployment is still distressingly common among them. But one must not let temporary conditions warp one's judgment as to permanent trends. The real question is, "Over the working lifetime of a young man now choosing a career, is engineering going to be overcrowded?"

General Rees, Vice President of the American Telephone and Telegraph Company put that question to his statistical staff last winter. In answer, they gave him a curve showing how many engineers are being graduated, year by year, from all the schools of the country from about 1920 through 1937. The last four years of this curve are, of course, predictions, but fairly accurate predictions, for we know how many men entered engineering schools last fall and the fall before that and so on, and we also know from experience about how many of each of these groups is going to graduate. So we can draw the curve with some confidence through June 1937. The general trend of the curve is unmistakably upward as is indicated by the trend line which the industrial statisticians drew, a trend line which slopes up from a little less than 9000 graduates in 1921 to nearly 11,000 in 1937.

Fewer Engineers Graduated this Year

This trend line may safely be taken, I think, as a measure of the normal demand for engineering graduates. The curve itself varies, however, above and below its trend line as the years go by. From about 1927 to about 1933 it was above the trend line; that is, we were graduating more engineers perhaps than we should have. This June we shall have graduated, the country over, distinctly fewer engineers than the trend line indicates to be desirable, and in 1935, 1936 and 1937 the number will be markedly below normal. Indeed, in 1937 it looks as if we would be graduating something like 3500 too few men to match the normal trend; that is, we shall be turning out barely two-thirds as many engineers as we ought to. By 1938, when a young man entering college this coming fall would normally graduate, it seems clear that the accumulated deficiency in engineering graduates will more than equal the accumulated surplus during the preceding period of educational prosperity.

I can defend this statement by quite another sort of evidence. Over a year ago James A. Farrell, then just retiring from the presidency of the United States Steel Company, said to a group of friends that he had no question but that American industry would soon find itself facing the worst shortage of technically trained men it had ever known. He said that this would be true at all occupational levels from machinists and other skilled workmen to research men with doctor's degrees. He said that such a shortage had appeared after every previous depression in industrial history, and that, to the extent that this depression has been severer than usual, the ensuing shortage of technically trained men will be severer than usual also.

At the time, that statement seemed to an engineering educator altogether too good to be true. But as the months have rolled by and I have watched events with that statement vividly in mind, I have become convinced that it is sober fact. Already on the skilled trade level, acute isolated shortages are beginning to appear. On the college graduate level of technically trained men things will undoubtedly work out rather differently in detail. We shall have no similar acute little shortages in isolated specialties here and there, for one of the essential differences between college trained men and skilled artisans is the greatly superior versatility and adaptiveness which a broad engineering training produces. If there is a special demand for any particular kind of engineer, there are always plenty of men in a wide variety of related specialties who can become competent in the desired field almost over night. Among college trained technical men the impending general shortage will come, not as a succession of acute shortages in specialties, but rather as a gradual and largely unperceived reabsorption into industry of the whole floating supply of

* From a radio talk.

men of a given age and experience level. The change from a buyer's to a seller's market for engineering services is likely to come rather suddenly, and perhaps unexpectedly, when it comes.

And yet, already occasional straws are showing which way the wind is blowing. For instance, nearly three quarters of last year's graduating class at Stevens now have jobs, a record that would have delighted any college administrator's heart a year or two ago. More and more I am convinced that Dr. Farrell was right when he said, fifteen months ago, that American industry is soon going to have to face a severe shortage of technically trained men.

Field of Engineering Broadening

I have still a third reason for believing that engineering is not going to be overcrowded during the quarter century that lies ahead. It is that the scope and range of the engineering field is continually broadening. The whole electrical field has grown up from nothing in the last half century, the automobile field in the last third of a century and the airplane field in twenty-five years. What is going to happen next is on the lap of the gods. One can only say that industrial research has been unusually active during these depression years. Air conditioning, the re-design not only of railroad rolling stock and automobile bodies but perhaps even of boats, marked advances in the aeronautical field, revolutionary new processes and products in metallurgy and in the heavy chemical industries, television, the mass production of housing, slum clearance and the replanning of cities; all these and a host of other developments lie ahead. Any one of them may require hundreds of engineers of some new kind at any minute. How can so imaginative and constructive a profession be more than temporarily overcrowded?

Furthermore, it should be remembered that management and industrial engineering are historically children of mechanical engineering, that they are now well established fields in their own right and still growing rapidly and that an engineering training always has been, and still is, the best sort of background with which to enter upon these important and attractive careers. Many of the foremost industrial consultants of today are engineers. Already a considerable number of the major and minor executives of business and industry have been drawn from our profession, and there is every indication that the number will increase in the future. Indeed, business and industry, as distinguished from the more professional and technical activities of a strictly engineering sort, already attract more than half of all the engineering graduates of the country, so that training for business and industry may almost be regarded as the major function of a school of engineering. It is for this reason that engineering schools all over the country have begun to lay such stress on economics in their curricula.

The broad field over which so many engineering graduates already are ranging in business and industry also explains why so many modern engineering schools are stressing a strong background of the humanities, particularly the important arts of written and oral expression; but also including literature, history, government and philosophy. As long as an engineer remains a mere technician, no matter how skillful or on how high a plane, he will never play the part in shaping the destinies of the community that his capacity and training indicate as his responsibility. He must be as well educated as the lawyer, the doctor or the banker if he is to share with them the job of molding twentieth century civilization.

Scarcity of Engineers Predicted

Is, then, engineering overcrowded? I confidently answer "No." Four years from now there won't be enough engineering graduates to meet even the technical demands of the profession to say nothing of all the other opportunities for constructive leadership that lie ahead. No profession can ever be overcrowded that is based on so happy a combination of idealism, imagination and rigidly sound straight thinking as that which characterizes engineering.

Electricity Production Reaches High Mark for the Year

The output of electricity for the week ending June 30, as reported by the Edison Electric Institute, shows a high mark for this year with a production of 1,688,211,000 kwhr. This is since January 24, 1931 and 2 per cent above the corresponding week of last year, at which time, it will be recalled, the curve was going up rapidly. The production index, adjusted for seasonal variation and with 1929–1930 taken as 100, shows the week of June 23, 1934 up to 99.7. In March 1933 the index dropped to 79.

The use of electricity may be taken as a fairly good indication of industrial activity. While the foregoing figures apply to the country as a whole, recent weeks have shown New England to have fallen behind the corresponding period of last year.

Pipe Standards Approved

The American Standards Association has recently approved nine standards for wrought-iron and steel pipe. These include:

1. Standard Specifications for Welded and Seamless Steel Pipe.
2. Standard Specifications for Welded Wrought-Iron Pipe.
3. Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service.
4. Tentative Specifications for Electric-Fusion-Welded Steel Pipe (sizes 30 in. and over).
5. Tentative Specifications for Electric-Resistance-Welded Steel Pipe.
6. Tentative Specifications for Forge-Welded Steel Pipe.
7. Tentative Specifications for Lock-Bar Steel Pipe.
8. Tentative Specifications for Riveted Steel and Wrought-Iron Pipe.
9. Tentative Specifications for Electric-Fusion-Welded Steel Pipe (sizes, 8 in. to but not including 30 in.).

These standards culminate over seven years of research and committee work under the leadership of the A.S.T.M. and the A.S.M.E. with numerous other societies and trade associations cooperating.

Arc Welding and Some of Its Applications*

By J. E. WAUGH
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Welding is of two general classes, plastic and fusion. In plastic welding, the parts are heated to welding temperature after which the weld is completed by application of pressure or blows. The most common plastic welding processes are forge welding and the electric resistance process with its sub-divisions of butt, flash, seam, spot and projection welding. Fusion welding is the process of joining metal parts in the molten, or molten and vapor states without the application of pressure or blows. It includes the gas, thermit and electric arc processes. Electric arc welding has two general subdivisions, namely: carbon arc and metallic arc welding. The latter is here discussed with special reference to welding of the mercury-steam installation at Schenectady.

INTRODUCED as a repair medium, metallic arc welding has progressed until today it is accepted as a necessary tool in the fabrication of many structures. No other branch of industry can boast of a more rapid or more successful rise to prominence. In common with most repair methods, arc welding in its early stages was a more or less hit or miss proposition. However, with its growth, the need for proper supervision and procedure control was recognized. We now have such codes as the A.S.M.E. Fired and Unfired Pressure Vessel Codes and the American Welding Society Code for the welding of Structural Steel, as rules and guides for the proper fabrication of welded structures. Moreover, most of the larger users of arc welding are realizing the importance of periodically qualifying their welding operators.

The first metallic arc welding done in this country involved the use of bare and lightly coated electrodes, and it was on the basis of results obtained with these electrodes that design values were established. The Structural Steel Committee of the American Bureau of Welding, after conducting an extensive series of tests covering a period of five years and including welded specimens made in shops over a considerable area of the country, recommended the following recognized design values based on a factor of safety of four: tension 13,000 lb per sq in., shear 11,300 lb per sq in. and compression 15,000 lb per sq in.

While weld metal and welded joints made with bare or lightly coated electrodes are usually satisfactory for static loads, they are lacking in ductility, impact and fatigue strength and corrosion resistance. An effort to improve these qualities led to the introduction of the heavily coated electrode. Physical tests of weld metal deposited with this type of electrode produce results comparable to good-quality mild-steel plate. The following table states comparative values obtained with the two classes of electrode.

COMPARATIVE PHYSICAL PROPERTIES OF WELDS AND WELDED JOINTS MADE WITH BARE AND HEAVILY COATED ELECTRODES

	Bare Electrodes	Heavily Coated Electrodes
Welded Joints		
Tensile strength in lb per sq in.	50,000–55,000	Fracture in plate
Per cent elongation in free-bend test	10–15	30–50
All weld metal		
Yield point in lb per sq in.	40,000–45,000	50,000–55,000
Ultimate tensile strength in lb per sq in.	50,000–55,000	60,000–70,000
Per cent elongation in 2 in.	5–10	20–30
Per cent reduction of area	10–20	35–50
Charpy impact in ft-lb	2–5	20–30
Density	7.70	7.82
Endurance limit in millions of cycles	10–15	20–30
Corrosion—(mild-steel plate as 100 per cent)	50	95–100

These superior physical properties are due to the shielding of the molten metal while passing through the arc, thus eliminating the oxides and nitrides which have a great affinity for molten iron at the arc temperature, which is estimated to be approximately 3500 C. The procedure in depositing weld metal with heavily coated electrodes, that of making the individual passes or layers relatively thin (of the order of $^1/_8$ in.) also results in an improvement of its physical properties because of the refining effect of each succeeding pass on the preceding pass. A still further improvement in ductility is accomplished by subjecting the completed weld to a strain relief anneal at 1200 F.

It is natural to assume that heavily coated electrodes will replace bare electrodes. The tendency is decidedly in this direction and the writer believes that it will eventually occur but not in the immediate future. The chief factors which prevent an immediate change are: (1) the cost differential of the electrode itself, a ratio of two or three to one in favor of bare electrodes; (2) the increased cost of labor in depositing the metal, this being due largely to the time involved in removing the slag between passes and (3) the necessity of training welders in the use of heavily coated electrodes. The education of engineers and the public in general in the superior qualities of heavily coated electrodes will help materially their further use and result in the ultimate displacement of bare electrodes.

Heavily coated electrodes have played a very important part in the fabrication of the new mercury-steam

* Presented before the International Business Machines Club at Binghamton, N. Y.

power plants erected by the General Electric Company. In fact their use was mandatory in order to meet the requirements of the Hartford Steam Boiler Insurance and Inspection Company for Class I vessels as specified by the A.S.M.E. Boiler Code.

The recently completed power station at Schenectady is truly a monument to arc welding. While it is classified as an outdoor station, since the mercury and steam turbines are exposed to the weather, the boilers, fuel-burning and other equipment are housed in an arc-welded building. Bare electrodes were used in the fabrication of the structural work and heavily coated electrodes on all mercury turbine equipment and pressure piping. The system involves vaporizing the mercury in a pulverized-coal-fired mercury boiler, the vapor being delivered to the mercury turbine at a pressure of 125 lb at 958 F. After developing 20,000 kw in the mercury turbine, the exhaust vapor passes into condenser boilers. This condensation results in a transfer of heat from the mercury to generate 325,000 lb of steam per hour at 450 lb pressure. The liquid mercury from the condensers is pumped back into the mercury boiler where it is again vaporized. From this description, the importance of having a closed system to prevent the loss of mercury is very evident. Welding the joints with heavily coated electrodes has assured the absence of leaks.

All piping in the mercury and high-pressure steam systems was welded to meet the A.S.M.E. Unfired Pressure Vessel Code for Class II vessels. Most of the piping in the station itself was of such a nature that welds were made in position, requiring vertical and overhead welding on pipe diameters varying from two to eighteen inches. Type W-20 electrode, $^5/_{32}$ in. in diameter, was used for this work at approximately 150 amperes, the weld being deposited in several passes, the thickness of each pass being $^1/_8$ to $^5/_{32}$ in.

One of the features of the installation was a 14-in. diameter, $^1/_2$-in. wall, seamless-tubing steam line 4800 ft long and operating at 400 lb pressure at 750 F. The length and contour of the tunnels and bridges carrying the line permitted the use of roll welds in many sections. Six or seven 35-ft sections of pipe were tack-welded together and rotated mechanically on rollers at a peripheral speed of from six to ten inches per minute, depending on the width of the groove. The pipe ends were mill-beveled to provide an included angle at the joint of 60 deg; were spaced $^3/_{16}$ in. and backed up by a $^1/_8$ in. $\times$ 1 in. steel chill ring. Each weld was made in five passes, the first pass being made with $^3/_{16}$ in. diameter type W-21 electrode and the remaining four passes with $^1/_4$ in. electrode of the same type.

Welding specifications covering the design of joints and the proper welding procedure were strictly adhered to in this entire installation. All welders were required to pass qualification tests before being permitted to do any work. Completed welds were also removed from the lines during installation and tested. It is interesting to note that these test specimens were better than those made on qualification tests. In all tensile tests, fracture occurred in the plate well outside the weld. Free bend tests produced an average of 50-per cent elongation of the outer fibers.

The Reynolds Number

By D. S. CLARK

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WHEN a fluid is being transported in a pipe and comes in contact with the pipe surface at any relative velocity, producing flow and friction, four factors must be taken into consideration, namely, the velocity, the density, the viscosity of the fluid and the diameter of the pipe. Professor Osborne Reynolds[1] deduced the following relation among these four factors, which expressed mathematically, is called the Reynolds number (R):

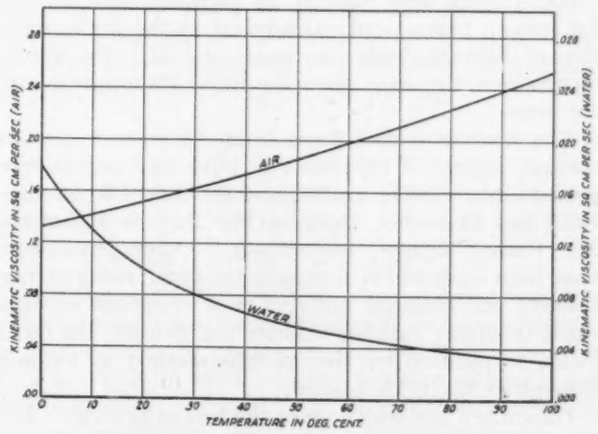
$$R = \frac{VDS}{U}$$

In English units, V is the velocity in feet per second, D is the pipe diameter in feet, S is the density in pounds per cubic foot and U is the absolute viscosity. The absolute viscosity or internal fluid friction may be defined as the force required to move a plane surface of unit area, parallel to another plane surface of the fluid at a unit distance with unit relative velocity. Absolute viscosity has no definite unit measure in the English system; but in the c. g. s. system, the unit is the *poise* which is expressed as 1 dyne second per square centimeter. This force can be converted to English units by dividing by 14.88 to obtain a poundal second per square foot. Charts are available showing the viscosity of various liquids, gases and vapors in both systems.

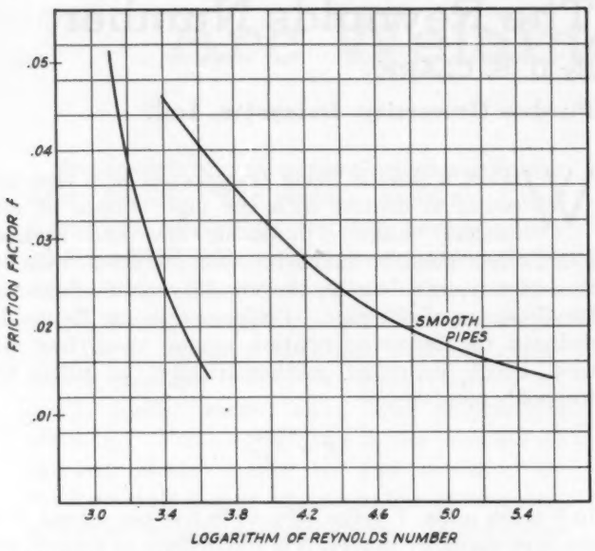
The viscosity, U, is not available for all temperatures, but in the case of perfect gases, if the viscosity is available at any temperature, it can be computed for other temperatures, by Sutherland's formula:

$$U = U_0 \frac{(T_0 + C)}{(T + C)} \frac{(T)^{1.5}}{(T_0)}$$

The zero subscripts represent known viscosity (U) in poises at the absolute temperature (T) centigrade, whereas the variable viscosity and temperature have no subscripts; C is a constant for any given fluid. The above method suffices for low pressures but requires a verification for high pressures.



Kinematic viscosity of water and air



Relation of friction factors and Reynolds Numbers

Tables and charts are available which record the kinematic viscosity, (Y), which is found by dividing the absolute viscosity (U) by the density (S), so that the equation expressing the Reynolds number (R), becomes

$$R = \frac{VD}{Y}$$

Regardless of the system of units employed, the Reynolds number for any set of conditions is constant, providing that consistent units are followed. Even with a system introducing convenient units a constant may be introduced as a conversion factor.

Extensive experiments have been performed and show that when friction factors are plotted against the Reynolds number a smooth curve results for values of R above 3000 (sinuous or turbulent flow) and another smooth curve for values of R below 2000 (straight line flow). Reynolds numbers between 2000 and 3000 represent the unstable region of critical flow. Thus practically all industrial flow processes produce Reynolds numbers which appear on one of the smooth curves. These curves were plotted by Stanton and Pannell[2] for smooth pipes; and, on account of the similarity of flow of different fluids (air, water and oil); the friction factors were the same when the Reynolds numbers were the same.

The friction factors have been determined also for various degrees of roughness in pipes and papers were presented before the meetings of the A.S.M.E. in June, 1932, and December, 1932, by Mr. R. J. S. Pigott and Mr. Emory Kemler, respectively. Other experiments have been made which determine the factor using average velocity and constant density. For extremely accurate work, involving variable velocity and density, the factor yields to solution by the calculus method as followed through by W. H. McAdams[3].

Poiseuille's law which gives the loss in pressure (ΔP), due to fluid friction, is expressed in terms of the friction factor (f) as follows:

$$\Delta P = H_f S = f \frac{(L)}{(D)} \frac{SV^2}{2g}$$

In these cases H_f is loss of pressure head in feet of the fluid; L is the length of straight pipe in feet; D is the pipe diameter in feet; S is the density in pounds per cubic foot; V is the velocity in cubic feet per second and g is 32.17. This, of course, gives ΔP in pounds per square foot, but dividing both sides of the equation by 144, we have

$$\Delta p = \frac{fLV^2S}{9264\,D}.$$

This method of approach is logical and should be a basis for determination of pressure losses in a line to within any accuracy imposed, since the friction factor is determined upon a dimensionless ratio. Similarity of flow allows the calculations to be extended to other fluids. This analysis is also appreciable to other cases in which a fluid comes into contact with a surface such as in airplane or automotive design.

Dr. Reynolds' determination, "that the general character of the motion of fluids in contact with solid surfaces depends on the relation between a physical constant of the fluid and the product of the linear dimensions of the space occupied by the fluid and the velocity," is a major contribution to accurate analysis of fluid flow and friction.

(1) Dr. Osborne Reynolds, Philosophical Transactions of the Royal Society, London, 1883, Vol. III.
(2) T. E. Stanton and J. R. Pannell, Philosophical Transactions of the Royal Society, 1914, A214.
(3) W. H. McAdams, Heat Transmission—published by McGraw-Hill Book Co.

Coal Industry Attacks T.V.A.

Alabama coal operators, with implied endorsement of the National Coal Association has filed action in the Federal District Court in Birmingham, Ala., challenging the right of the Tennessee Valley Authority to engage in a large scale power business. They contend that the T.V.A. in its program for generating, distributing and selling electrical energy is exceeding its constitutional powers as stated in the original Tennessee Valley Authority Act which provided for the operation of the Muscle Shoals plants, the development of agriculture and industry, improvements in navigation and the promotion of national defense. It is contended further that the federal power projects are economically unjustified and constitute a grave menace to the bituminous coal industry and will lead to further unemployment within that industry.

Boiler Manufacturers Elect Officers

At the forty-sixth general meeting of the American Boiler Manufacturers' Association held at Sky Top Lodge, June 11–14, the following officers were elected:

President, Owsley Brown, Springfield Boiler Company
Vice President, S. H. Barnum, The Bigelow Company
Executive Committee, F. H. Daniels, Riley Stoker Company; M. E. Fink, Murray Iron Works; A. G. Pratt, Babcock & Wilcox Company; A. C. Wiegel, Combustion Engineering Company; and Walter F. Keenan, Jr., Foster Wheeler Company.

Turbine Plant Efficiency Calculations

By JULIAN C. SMALLWOOD

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A discussion of the standard for steam turbine efficiency proposed several years ago by Darrieus. The author attempts to present this in somewhat simplified form and considers it with special reference to extraction and reheat cycles.

ALTHOUGH nearly four years have passed since G. Darrieus published his rational standard for steam turbine efficiency, it has not yet come into general use. This may be due to lack of understanding of the subject, since the existing expositions of it are rather involved. The best of these is by J. H. Keenan[1] to which the reader should refer for more detailed discussion. The writer has incorporated some of Professor Keenan's ideas in the present article. It is the purpose here to present it as briefly and simply as possible.

The following notation will be used in this article:

h = enthalpy (total heat) of steam or water, Btu per lb
s = entropy, Btu per lb per deg F
T' = lowest available temperature of system, deg F, absolute = temperature of incoming condenser circulating water, or as fixed by other considerations later mentioned.
$b = h - T's$ = "availability function."

Subscripts 1, 2, 3, etc., define values of h, s and b at conditions shown by corresponding points on the T-s diagram, Fig. 1.

Fig. 1 is a temperature-entropy diagram of the changes in steam passing through a three-stage turbine, initially saturated and ending at temperature T'. The total available energy is the sum of the three cross-shaded areas defined by the assumption of isentropic expansion. In the first stage, the actual path of the steam is 1–3, and the work, $h_1 - h_3$, is less than the available energy of that stage because of reheating effects. These reheating effects increase the enthalpy of the steam leaving the first stage, and make a greater amount of energy available in the remaining stages, as indicated by the vertically shaded area, q, than that for isentropic expansion from the initial condition.

[1] *Mechanical Engineering*, March 1932.

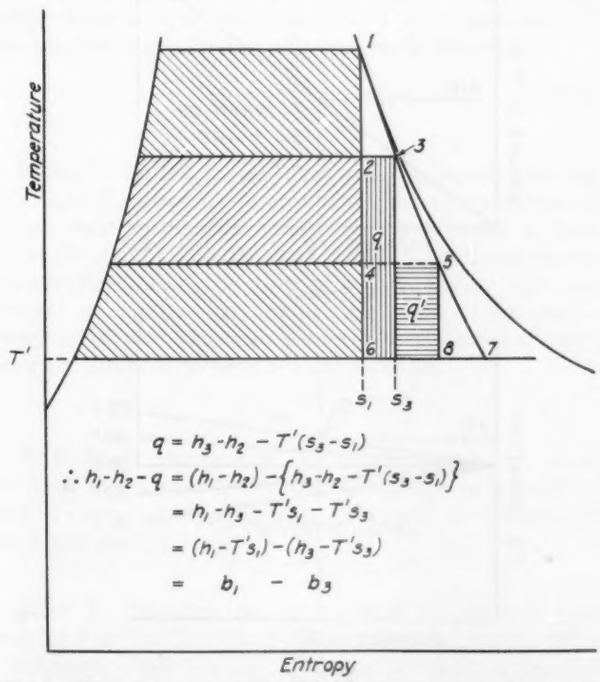

Fig. 1—The idea underlying the Darrieus proposal is to give each stage credit for that part of the energy unavailable to it but recoverable in succeeding stages

The conventional expression for stage efficiency is the ratio between the heat actually converted into work and the available energy during isentropic expansion. For the first stage, Fig. 1, the conventional efficiency is $(h_1 - h_3) \div (h_1 - h_2)$. This standard does not give credit to the first stage for that part of the energy made unavailable in it which is theoretically recoverable in succeeding stages; that is, for area, q. The idea underlying the Darrieus proposal is to give each stage credit for this recoverable energy. Accordingly,

$$\text{Efficiency} = \frac{h_1 - h_3}{h_1 - h_2 - q}$$

Inspection of the area relations of Fig. 1 shows that the denominator of this fraction,

$$h_1 - h_2 - q = (h_1 - T's_1) - (h_3 - T's_3)$$

It is thus seen that the heat charged against a stage in which the steam changes along a polytropic adiabatic, as 1–3, equals the change in the value of a function $h - T's$. This is not the Gibbs function although it is like it in form. It might appropriately be referred to as the "availability function." It will be symbolized by the letter b. The efficiency of any stage is then $(h_1 - h_3) \div (b_1 - b_3)$, subscripts 1 and 3 denoting actual entering and leaving conditions of that stage. This efficiency differs from the conventional efficiency less for the low-pressure stages than for the high. For the second stage, (see Fig. 1), the increment of energy, q',

available in the third stage, because of reheating effects in the second, is less than q. For the third stage the increment becomes zero and $b_5 - b_7 = h_5 - h_8$.

The isentropic heat drop, $h_1 - h_2$, is the maximum amount of energy convertible into work under ideal conditions. If work could be realized in this way in a steam turbine, the steam would *lose* energy in equal amount, and the loss of availability could be written $h_2 - h_1$, a negative quantity. Similarly, $b_3 - b_1$, is the *decrease* in availability of the steam when the path is not isentropic, but along some adiabatic 1–3. The function, $h - T's$, thus is a measure of availability regardless of the path. To summarize:

Available energy (maximum work)	$= h_1 - h_2$
Actual work	$= h_1 - h_3$
Decrease in availability, path 1–3	$= -(h_1 - h_2 - q) = (b_3 - b_1)$
Efficiency, first stage	$= (h_1 - h_3) \div (b_1 - b_3)$
Efficiency, second stage	$= (h_3 - h_5) \div (b_3 - b_5)$
Efficiency, third stage	$= (h_5 - h_7) \div (b_5 - b_7)$
	$= (h_5 - h_7) \div (h_5 - h_8)$

A further study of the quantity, b, shows that it is a measure of availability whether heat is converted into work or not, and regardless also of the process involved. It is a more important quantity, in this connection, than is enthalpy, h. Increases in the value of b anywhere in the system mean gains in availability, and are imparted by feed pumps, drip pumps, boiler, superheater and resuperheater. Conversely, decreases of b indicate loss of availability which may or may not be accompanied by a conversion of heat into work. In the turbine, the steam loses availability and there is a gain in work. In the condenser and extraction heaters, there is a loss of availability without gain in work.

This greatly simplifies the problem of making an energy balance. We charge to the plant, or any part of it, increases in b, of the working medium, and give credit for work conversion. Thus, considering a bleeder turbine, if a fraction of a pound of steam, w, entering under initial conditions, 1, is extracted, or flows to the condenser, at condition, 3, the loss of availability is $w(b_3 - b_1)$ and the heat converted into work is $w(h_1 - h_3)$. The overall efficiency of the turbine is then:

$$\Sigma w(h_1 - h_3) \div \Sigma w(b_1 - b_3)$$

Using this expression, no laborious corrections need be made when conditions are different from those set for guarantee, such as undercooling of condensate, etc. When steam is extracted for process work, only that part of its availability, $w(b_1 - b_3)$ is charged against the turbine.

That change in the value of b gives a much better picture of gain or loss of availability than does change in the value of h is illustrated by the following. In a feedwater heater, heat passes from relatively high-temperature steam to low-temperature feedwater. This is an irreversible process necessarily accompanied by loss of availability. Disregarding radiation losses, the enthalpy increase of the feedwater equals numerically the enthalpy decrease of the steam; the algebraic sum of the enthalpy changes is zero; and from the consideration of enthalpy alone, it would appear that there is no loss. On the other hand, if one refers to the b values, it will be found that the increase of b for the feedwater is numerically less than the decrease of b for the steam; the algebraic sum of the b changes is therefore negative and its magnitude indicates a net loss of availability.

For the power plant as a whole, changes of availability may be written Σwb under conditions *leaving* the unit and considered minus Σwb under *entering* conditions. If the difference is plus, there is a gain; if minus, there is a loss. The minus values are unaccompanied by work in the condenser, feedwater heaters, and all units except the main turbines.

The base temperature, T', may be chosen according to the object in mind when calculating results. If it is to compare the performance of one turbine with another, then it appears reasonable to take T' as that of saturation at the pressure of exhaust. If the purpose is to evaluate power plant processes in their entirety, then it is proper to use the temperature of the incoming circulating water supplied to the condensers.

Although it is desirable to have tabulated or charted values of b for all power plant conditions of steam and

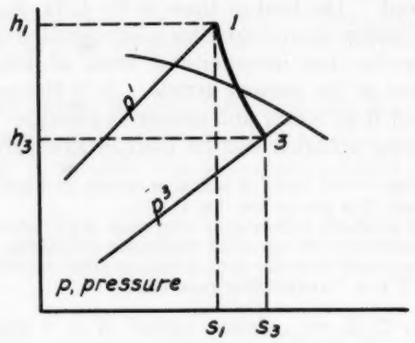

FIG. 2

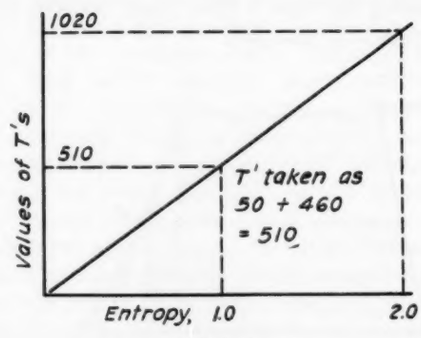

FIG. 3

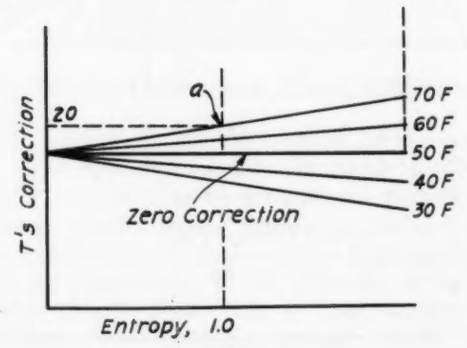

FIG. 4

Fig. 2—Represents path of steam through a stage. Fig. 3, shows a variation of T with S. Fig. 4 correction chart.

water for various values of T', it is not necessary since any desired value of b, or changes in b, may be readily calculated.

Fig. 2 represents the path of steam, 1–3, through a turbine stage. If the lowest available temperature is taken as 50 F, then $b_1 = h_1 - 510\,s_1$ and $b_3 = h_3 - 510\,s_3$. The difference, $b_3 - b_1 = h_3 - h_1 - 10\,(s_3 - s_1)$.

It is interesting to note the difference between the magnitudes of h and b. Thus:

	h	b
Saturated liquid, 14.7 lb	180	29
Saturated steam, critical pressure	925	375
Peak of saturation curve, h-s chart	1204	450
Saturated steam, 0.75 lb	1100	80

For convenience Darrieus and Keenan proposed a $b-s$ chart to enable the determination of b without calculation and to show the $b-s$ changes of steam for any process, by a path or series of paths. In the expression, $b = h - T's$, the quantity $T's$ varies directly as s, if T' is fixed.

Fig. 3 shows its variation with s for $T' = 510$. If, now, an $h-s$ diagram, with the same scale of coordinates, and zero h and zero s at the origin, be superposed on Fig. 3, the b value for any point on the $h-s$ diagram may be found by measuring its height above the diagonal of Fig. 3. In this way a $b-s$ diagram may be evolved appropriate to a base temperature of 50 F, having all the characteristic lines of the $h - s$ diagram. To use this chart, when the base temperature is different from 50 F, a correction chart, Fig. 4, may be applied. Thus, if the entropy is 1.0, and the base temperature 70 F, the correction (point a, Fig. 4) is 20, which must be subtracted from the b value as found from the chart plotted for a base temperature of 50 F.

In conclusion, this method of judging steam boiler and plant performance seems logical and adaptable. Particularly in the case of extraction and reheat systems, it will be found not only to simplify arithmetical procedure, but make it unquestionably definite. The writer believes that, with the extension of knowledge of the principles involved, it will come into general use.

Frank G. Cutler, for 28 years with the Tennessee Coal, Iron and Railroad Company, and chief of its bureau of steam engineering, died suddenly in New York on June 17 at the age of 53. He was buried from his home in Birmingham, Ala., on June 21. Mr. Cutler was well known in mechanical engineering circles and was a member of the American Society of Mechanical Engineers, in addition to several local societies.

R. C. Muir has recently been appointed a vice president of the General Electric Company in charge of the engineering department. He will be located at Schenectady.

John C. Hopkins has been appointed district sales manager of the Cleveland office of General Refractories Company, Philadelphia. He was formerly associated with the Central furnace division of the American Steel & Wire Company, Cleveland, and has held various posts at all of that company's blast furnace plants.

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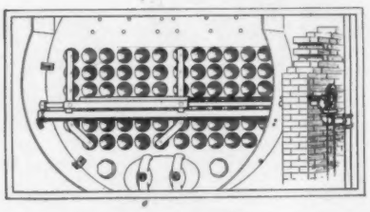
EDWARD VALVES

NEW EQUIPMENT

of interest to steam plant engineers

Straight-Line Soot Blower

Diamond Power Specialty Corporation, Detroit, has just brought out a soot blower for horizontal return-tubular boilers. This operates on the "straight-line" principle and has no swivel joints nor flexible hose connections. Referring to the illustration, the soot blower is in-

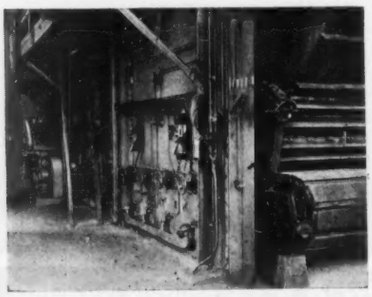


stalled in the uptake and the two vertical blowing elements, containing the nozzles, traverse across the ends of the tubes. These elements are shown in the extreme left position. By pulling the right-hand chain, the elements are traversed toward the right until they reach the other extreme position where further rotation of the chain wheel is prevented by a stop.

Traveling Grate Stoker

To adapt the well-known Coxe Stoker to wider furnaces, hence larger capacities in the burning of small sized anthracite, coke breeze, lignite and certain non-caking bituminous coals, under forced draft, Combustion Engineering Company has brought out what is designated as the "CD Design." This employs two or more carrier bars placed end to end instead of a single bar across the stoker as in the older design where the length of the bar was necessarily limited in order to avoid warping. These bars carry cast-iron keys the overlapping construction of which prevents ash being carried back to the front of the stoker.

The stoker body is built up of structural steel cross members which, in turn, support the skids and grate surface. This is in contrast to the smaller Coxe stokers in which the skids are supported on the box structure comprising the several air



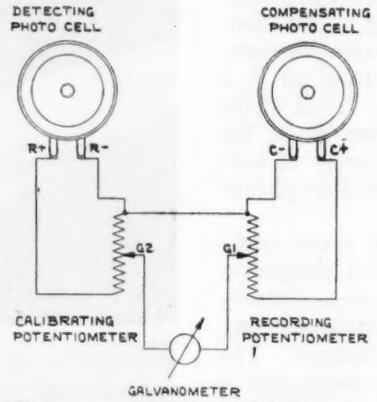
compartments. These compartments are formed by plates attached to the cross members so as to form a trough and steam or air jet blowers are placed at the sides to blow siftings into the longitudinal trough. Air is distributed to the compartments from air chambers beneath the side walls and the use of ducts is therefore avoided. Handwheels at one or both sides of the setting permit individual air control to each compartment. Preheated air may be employed.

As in the smaller design the stoker is driven from the rear shaft with the take-up for the driving chains located at the front.

The new design applies to furnace widths of 12 to 24 ft whereas the oldee type, with the single-bar design was limited to 11 ft $8^1/_8$ in..

Smoke Recorder

A new photo-cell, smoke-density recorder, compensated for variations in light source intensity and operated by the Galvatron Electronic Relay Circuit, has been announced by Bailey Meter Company, Cleveland, O. This equipment consists of a receiving element in the form



Compensating Photo Cell Circuit

of a recorder, usually mounted on the individual boiler panel board, and a transmitting element consisting of a projecting cylinder and a detecting cylinder which are mounted on opposite sides of the breeching or flue gas passage. Two photo cells are employed in the transmitting element, one in the projecting cylinder and the other in the detecting cylinder.

Full luminous flux from the incandescent lamp light source is received by the compensating cell at all times regardless of the smoke density condition within the gas passage. However, the photo cell located in the detecting cylinder on the opposite side of the gas passage receives light of varying intensities, depending upon the density of the smoke in the passage.

The method by which variations of light source intensity, are compensated for, is clearly shown in the accompanying electrical circuit diagram. To accomplish this, the calibrating potentiometer is connected in series with the detecting photo cell and the recording potentiometer is connected in series with the compensating photo cell. Negative terminals of both cells are connected so that they will be at the same potential.

When the light to the detecting photo cell is reduced by passage of smoke between the cell and light source, the voltage output of the cell is reduced and the potential of G_2 drops, causing a current flow in the galvanometer circuit. This unbalanced condition causes the galvatron to move contact G_1 toward the negative terminal until a decreased voltage point is reached comparable to that of G_2 when no current flows in the galvanometer circuit. Since this movement of contact G_1, necessary to balance the potential of G_1 and G_2 is proportional to the smoke density in the gas passage, moving contact G_1 is geared to the pen which records relative smoke density on the chart.

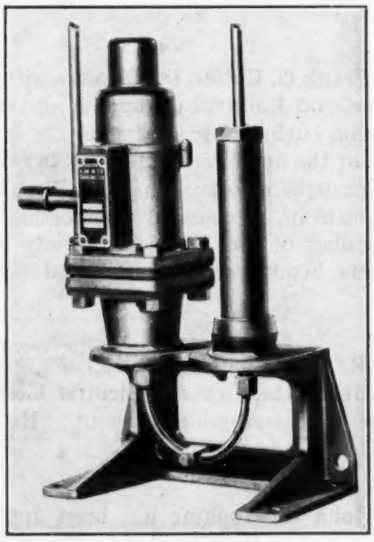
Since intensity variation of the light source changes the output of each cell in the same proportion, the position of the recording potentiometer contact G_1 is determined by the ratio of light intensities received by the two cells, and therefore records the true relative smoke density at all times, regardless of such factors as voltage variations and loss of incandescent lamp efficiency.

New Meter Body

The Brown Instrument Company of Philadelphia has brought out a new meter body for its electric flow meters. A seamless steel "U" tube with union compression fittings connects the high- and low-pressure chambers. A mercury drain mounted on this tube has a hardened needle point screw which seals the mercury drain hole in the "U" tube. Mercury cannot be blown out of this meter body under severe overload or reverse flow conditions. Two highly resilient seals of an oil resisting material, seat firmly in the high pressure chamber, one seal on top the float, one underneath. As the mercury level rises and falls with flow changes, the float in the high pressure chamber is free to move and accurately follows the mercury level.

Forged steel pressure chambers, heavy seamless steel tubing for the range tube and piping, with all copper gasketed fittings recessed, eliminates welding. Each meter body is tested to 5000 lb per sq. in.

The range of this meter body can be changed easily without shutting down the line. Nine interchangeable range tubes



with corresponding charts for the recording meter are available. Each range tube is furnished with the right length of pipe, range tube support and gaskets all assembled as one unit.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Boiler Meters

A new 32-page bulletin (No. 44-A) entitled "Savings Effected by Bailey Boiler Meters" has recently been issued by the Bailey Meter Company, Cleveland. This contains handy indexes of the type, size, methods of firing and methods by which savings are effected. Included are operating data showing the nature and amount of savings effected in over 20 typical installations of Bailey boiler meters, covering a wide range of fuels.

Boilers

An illustrated bulletin (No. 9–17) describing the new integral-furnace boiler recently offered by The Babcock & Wilcox Company as a complete unit for moderate steam capacities. The unit, which is of two drum design, has a water-cooled furnace, slag screen and employs the cross-flow principle with smaller tubes in the second and third passes.

Centrifugal Blowers

Single-stage centrifugal blowers and exhausters are described in Bulletin 120-B10, just published by Roots-Connersville Blower Corp., Connersville, Ind. A table lists capacities up to 8000 cfm at pressures up to 3 lb.

Type OI blowers have the impeller mounted directly upon the extended electric motor or steam-turbine shaft. In the Type OIB blowers, each unit has its own shaft and bearings, adapting them to coupled, geared or belted drives, and making this type blower especially suited to heavy duty service. Type A machines have the double inlet arrangement. All types have throttling or damper valves in the inlet, to regulate the volume of air. Casings are usually furnished in cast iron, but any machinable alloy or special metal may be had where conditions require their use. Impellers are designed to meet specified conditions, and may be either closed or open types. Aluminum alloy is standard material, but special impellers are available.

Centrifugal Pumps

A line of single-stage monobloc centrifugal pumps with the motor as an integral part of the unit is featured in a new bulletin issued by the Worthington Pump and Machinery Corporation, Harrison, N. J. Beside a description of the pumps, the bulletin includes rating tables for various sizes and information on the selection of a pump to meet given conditions. These pumps are suitable for boiler return systems, breweries, laundries, refrigerating systems and air-conditioning installations.

Combustion Meter

Catalog RA-34 of The Hays Corporation, Michigan City, Ind., covers combustion meters for determining CO_2 and CO_2 combined with records of over-fire draft and flue-gas temperature. Recorders, indicators and combination recorder-indicators are covered in forty-five types.

Fittings for Welding

A 64-page catalog, issued by the Taylor Forge & Pipe Works, Chicago, covers a complete line of seamless steel fittings for pipe welding. Tables of standards and dimensions for various types of fittings and price lists are included as well as a large number of stress curves. Practical examples are worked out showing how to apply these curves and the accompanying data.

Flexible Coupling

A circular recently issued by Poole Foundry & Machine Company, Baltimore, describes improvements made in the gear-type flexible coupling which now has one-piece construction for the sleeve instead of a welded-on end plate. The new construction affords much closer tolerance at the bearing points due to the sleeve remaining true and round. It is also said to be stronger and lighter.

Gas Analyzer

Bulletin 20, issued by the Ellison Draft Gage Company, Chicago, describes the new Ellison Portable Gas Analyzer—a compact and improved instrument for determining the analysis and temperature of flue gas.

General Catalog

The Link-Belt Company, Chicago, has issued a 1024-page catalog containing practical information on machinery made by that company. Among the equipment covered are elevating and conveying chains, elevator buckets, sprocket wheels, chain drives, power transmission machinery, variable speed transmission units, bucket elevators, apron conveyors, screw conveyors, belt conveyors, car dumpers, flight conveyors and coal- and ash-handling machinery.

Motorpump

The Cameron "Motorpump"—a pumping unit having built-in motor and pump rotor on the same shaft, and made in twenty-six sizes from 5 gpm to 1000 gpm—is described in Catalog No. 7464 recently issued by Ingersoll-Rand Company, 11 Broadway, New York. The catalog, besides being descriptive, contains numerous performance and dimensional tables.

Pulverized Fuel Equipment

A 24-page illustrated bulletin describing the impact- and ball-type mills and other pulverized fuel equipment, such as burners, controllers, valves, feeders, etc., as made by the Foster Wheeler Company, New York.

Refractory Products

A general catalog covering its jointless firebrick and refractory products has recently been issued by the Plibrico Jointless Firebrick Co. of Chicago. Various forms of arches and walls are illustrated by construction photographs.

Soot Blowers

A bulletin has just been issued by the Diamond Power Specialty Corp., Detroit describing its new "Straight Line" soot blower for horizontal return-tubular boilers.

Utility Air Hoists

Ingersoll-Rand Company, New York, has just issued a new bulletin, No. 12107, on their "Utility" air hoists. It describes both the single-drum air hoist, used for such work as hoisting materials, etc., and the double-drum air hoist, which is used for loading cars, drag line work, etc. The single-drum hoists are available in ten sizes, with capacities up to 2000 lb straight line pull. The double-drum hoists are built in four sizes up to 2000 lb capacity at various rope speeds. One size was especially developed for use with low-pressure air.

Non-Return Valves

Discussion of desirable characteristics of boiler non-return valves is found in a new 48-page booklet, Bulletin 11-T, issued by The Edward Valve & Mfg. Co., Inc., East Chicago, Indiana. In addition to photographs of a number of notable installations, a series of views in the Edward metallurgical laboratories, and a condensed catalog, the booklet contains a selected list, geographically arranged, of users of Edward non-return valves, taken from the sales records of a quarter of a century.

Welding

"The Testing and Qualification of Welders" is the title of a twenty-two page booklet issued by The Linde Air Products Company, New York, in which is outlined simple tests for measuring the ability of welders. The fracture, bend tensile and observation tests are described and discussed and there are included excerpts from the A.S.M.E. Unfired Pressure Vessel Code the A.S.A. Pressure Piping Code, and Specifications and Standards Covering Welding of Steel and Wrought Iron Pipe as prescribed by the Heating and Piping Contractors National Association. Helpful suggestions on oxwelding and cutting are appended.

NOTICE

Manufacturers are requested to send copies of their new catalog and bulletins for reviews on this page. Address copies of your new literature

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COMBUSTION

200 Madison Ave., New York

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Procedure Handbook of Arc Welding Design and Practice

(Enlarged Edition)

The Lincoln Electric Company has recently published a new and enlarged edition of its "Handbook on Welding," the original edition of which was completely exhausted shortly after publication.

This handbook is a compendium of pertinent information and accurate data on the subject of the art of arc welding, its applications, and design procedure for the most efficient use of the process. It was prepared not only for all welders and users or prospective users of the electric arc process of welding but also for those responsible for the design of products which may be built by welding.

Many additional pages of data, covering such subjects as Weld Inspection, Study of Stress Distribution, Approximate Method of Designing, etc., have been included in this enlarged edition; also additional data on procedures for welding mild steel, copper and aluminum.

The book is divided into eight principal sections or parts, each of which deals with an important phase of arc welding and its application in a clear, concise manner, amply illustrated with detailed drawings and photographs. The main headings are as follows: Welding Methods and Equipment; Technique of Welding; Procedures, Speeds and Costs for Welding Mild Steel; Structure and Properties of Weld Metal; Weldability of Metals; Designing for Arc-Welded Steel Construction of Machinery; Designing for Arc-Welded Structures; Typical Applications of Arc Welding in Manufacturing, Construction and Maintenance.

The *Procedure Handbook* is bound in semi-flexible Fabrikoid and contains 454 pages, size $5^3/_4 \times 9$, including a comprehensive index. Price $1.50.

Power Supply Economics

By Joel D. Justin and William G. Mervine

This book was written primarily for the executives and engineers of power companies and industrial concerns who may, in greater or lesser degree, be charged with the responsibility of maintaining or providing a dependable power supply.

Although the book treats of the broad general principles of the economics of power supply and does not go into technical details, the authors believe that engineers charged with the investigation, design and construction of power plants and the utilization of such plants to obtain the minimum system production cost will find in it much which is of interest.

Power Supply Economics indicates and describes principles and methods of analysis which will prove helpful in finding the most economical answer to problems which are constantly arising. The following questions, and many others, are fully discussed by the authors: Is our present cost of power the minimum which is obtainable with our existing facilities? What additional load must we be prepared to carry next year, and year after next? In order to carry this additional load, shall we build a new plant, or purchase power? If additional capacity is required, shall it be steam, hydro or Diesel? What shall be the capacity of the plant, and the size of the units? Shall the plant be built in such a manner as to provide for increase of capacity, and to what extent? As an alternative to building a new plant, cannot the required capacity be installed in an old plant, perhaps at the same time rejuvenating the old plant? Is it not possible to delay the construction of a new plant by making some reciprocal arrangement with a neighbor which will provide for interconnection and interchange of power, and also thus decrease power costs through the advantage of diversity?

This book contains 276 pages, size 6×9, and numerous illustrations and charts. Price $3.50.

Thermostats and Temperature Regulating Instruments

By Roosevelt Griffiths

The aim of this book is to give a sketch of the numerous types of thermostats, descriptions of which have heretofore been unpublished except here and there over a wide range of scientific periodicals.

This book will prove particularly helpful to the testing engineer who must have the latest data on the automatic control of the temperature of an enclosure or bath. To him, the right selection of a thermostat to suit his particular requirements is obviously of great importance.

In addition to the laboratory types of thermostats described, an account is given of coarser forms which find application in certain industrial operations.

Apart from its utilitarian value, the subject of thermostats is of interest in illustrating the diversity of phenomena which have been pressed into service in the design of scientific apparatus.

The following chapter headings indicate the scope of the subject matter of this volume: Thermostats Based on the Expansion with Temperature of Gases; Thermostats Based on Expansion of Liquids (Laboratory Types); Industrial Types of Thermostats Based on the Expansion of a Liquid; Mercury Expansion Thermostats; Thermostats Based on the Boiling Points of Liquids; Thermostats Based on Expansion of Solids; Bimetallic Type of Regulator; Resistance Thermostats; Temperature Control Using Radiant Energy; Contact Type of Regulator; Potentiometric Regulators; Induction Regulators; Low-Temperature Control.

This book contains 157 pages, size $5^3/_4 \times 9$, and many illustrations. Price $5.00.

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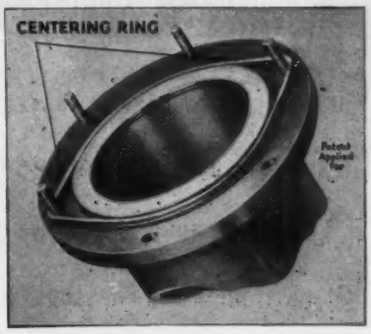

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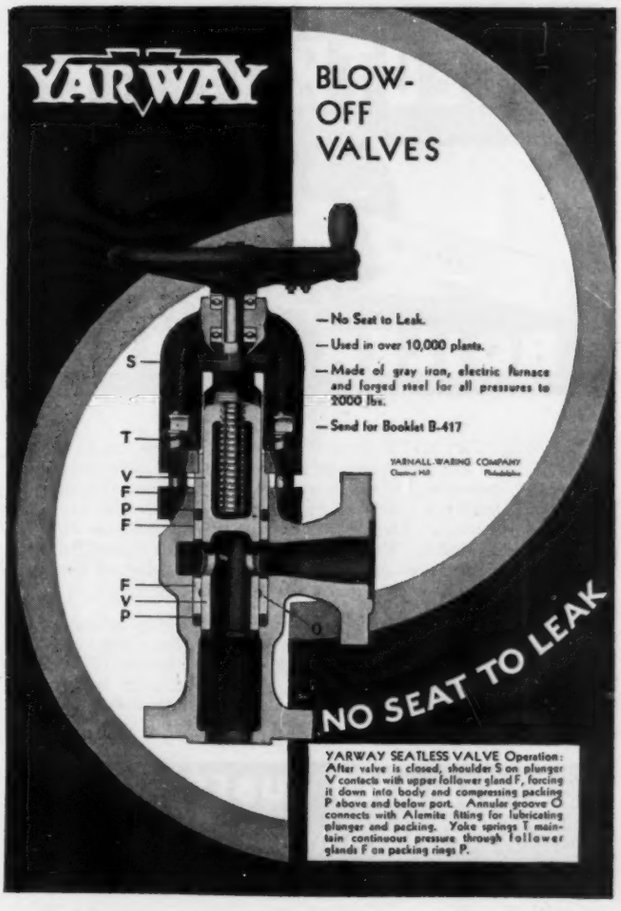
A.S.T.M. Officers, 1934–1935

The following officers of the American Society for Testing Materials for 1934–1935 were chosen at the Annual Meeting of that society at Atlantic City, June 26.

President—William H. Bassett, American Brass Co.; *Vice President*—H. S. Vassar, Public Service Electric and Gas Co.; *Executive Committee*—H. A. Anderson, H. J. Ball, W. M. Barr, L. S. Marsh and J. B. Rather.

Hirshfield Reports on E. C. P. D.

At the 50th Anniversary Meeting of the American Institute of Electrical Engineers, held at Hot Springs, Va., June 25 to 29, C. F. Hirshfeld reported on the proposals of the Engineers' Council for Professional Development as to the definition of engineering and the unification of membership qualifications among the various engineering societies. A minimum definition of an engineer is proposed which would demand graduation from an approved four-year (or longer) engineering course in an approved school or college, to be followed by four years or more of active practice and the passing of a written and oral examination covering technical, economic and cultural subjects. Eight years or more of acceptable practice would be an alternative to the college degree clause as a prerequisite for membership and governmental certification. Along with this it is proposed that all engineering societies have only student member, junior member and member grades.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As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 77 water-tube and h.r.t. boilers were placed in May

	Number	Square Feet
May, 1934	77	181,389
May, 1933	84	267,093
January to May (inclusive, 1934)	340	1,035,805
Same period, 1933	262	785,216

NEW ORDERS, BY KIND, PLACED IN MAY, 1933–1934

Kind	May, 1933 Number	May, 1933 Square Feet	May, 1934 Number	May, 1934 Square Feet
Stationary:				
Water tube	51	222,373	46	139,500
Horizontal return tubular	33	44,720	31	41,889
	84	267,093	77	181,389

Mechanical Stoker Sales

Orders for 145 stokers, Class 4,* totaling 28,005 hp were placed in May by 60 manufacturers

	Installed under: Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
May, 1934	110	16,287	35	11,718
May, 1933	54	7,695	44	16,152
January to May (inclusive, 1934)	369	49,272	165	68,719
Same period, 1933	244	33,586	131	46,378

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

No orders for pulverizers reported in May

STORAGE SYSTEM

	Total number	Pulverizers: No. for new boilers furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
May, 1934	..	..	..	.....	..	....	....
May, 1933	..	..	..	.....	..	....	....
January to May (inclusive, 1934)	2	1	1	46,000	*	*	*
Same period, 1933	2	..	2	60,000	2	37,000	325,000

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
May, 1934	..	..	..	....	..	....	.....
May, 1933	3	2	1	7,500	2	5,600	42,800
January to May (inclusive, 1934)	27	18	9	240,210	19	192,475	2,006,700
Same period, 1933	23	16	7	108,150	16	111,258	981,940
						Fire-tube Boilers	
May, 1934	..	..	..	....	..	....	.....
May, 1933	1	..	1	750	1	1,500	7,800
January to May (inclusive, 1934)	4	..	4	4,800	5	7,500	41,000
Same period, 1933	5	2	3	4,700	5	6,500	34,100

* Data not available.